THE UNIVERSITY OF ALBERTA

NORMS OF MAXIMAL OXYGEN CONSUMPTION FOR UNIVERSITY MEN

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Norms of Maximal Oxygen Consumption for University Men", submitted by Joseph L. Lovsin, in partial fulfilment of the requirements for the degree of Master of Arts.

ABSTRACT

The fundamental purpose of this study was to determine the PWC by establishing a table of norms of maximal oxygen consumption for first year University of Alberta men. The Astrand Bicycle Ergometer test was utilized. This test consisted of a six minute work period and a five minute rest that alternated until exhaustion. During the last minute of each work period a gas sample was taken and analyzed. While the test was being carried out heart rate readings were taken for the last five seconds of every minute by use of an electrocardiogram.

Other parameters considered in this study were: measuring pulse response to fixed work loads; a comparison of the non-smoking and smoking subjects as to maximal oxygen consumption and maximal heart rate; and a comparison of the results of this study to those from other countries completed by Rodahl *et al*.

The group of subjects that participated in this study numbered 100 and were healthy males chosen randomly from first year University of Alberta students in Edmonton. The age range was from 18 to 22 years.

The observations calculated for the table of norms indicated that the mean and standard deviation for the MVO_2 test expressed in litres per minute was $3.249 \pm .552$. The scores ranged from a low of 2.0451 to a high of 5.0366 l/m.

When the $\bar{X}MHR$ was calculated and a comparison drawn between the smokers and non-smokers, it was found that no statistically significant difference was indicated.

A comparison of $\bar{X}VO_2$ and $\bar{X}HR$ was carried out at 600 kpm between U of A men and Temple University men, ranging from 18 to 22 years of age,

and showed no statistically significant difference.

Similarly when the comparison of $\bar{X}MVO_2$ and $\bar{X}MHR$ was carried out between smokers and non-smokers no statistically significant difference presented itself. Within the limitations and assumptions of this study the following conclusions were drawn:

1. The table of norms has given a valid estimate of the MVO_2 performance of a random sample of first year men ranging in ages 18 to 22 at the University of Alberta, Edmonton, in the academic year 1963-64.

2. No statistically significant difference was shown to exist in $\bar{X}VO_2$ between U of A men in Edmonton at age 18, at 600 kpm, and the $\bar{X}VO_2$ of a similar group of individuals from Temple University of Philadelphia, Pennsylvania, U.S.A.

3. No statistically significant difference was found between the $\bar{X}VO_2$'s of U of A men in Edmonton and Temple University men ranging in ages 20-22 years old. The work load once again was 600 kpm.

4. Similarly it was shown that no statistically significant difference existed in $\bar{X}HR$ between U of A men in Edmonton, at age 18 and a work load of 600 kpm, and $\bar{X}HR$ of a similar group of individuals from Temple University of Philadelphia, U.S.A.

5. When the $\bar{X}HR$ of these same two samples was compared, at 600 kpm for men aged 20-22 years old, it was found that no statistically significant difference occured.

6. A comparison in $\bar{X}MVO_2$ of smokers and non-smokers was made, and the results showed no statistically significant difference between the two groups.

7. Similarly it was found that $\bar{X}MHR$ of smokers and non-smokers when compared, showed no statistically significant difference.

8. When the $\bar{X}$MHR of non-smokers was compared to those who smoked more than 16 cigarettes per day it was found that the non-smokers had a higher $\bar{X}$MHR.

9. When the $\bar{X}$MHR of non-smokers was compared to those who smoked between 0 and 5 cigarettes per day it was found that those who smoked had a higher $\bar{X}$MHR than the non-smokers.

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"If we take in our hand any volume ... let us ask; does it contain any abstract reasoning concerning quantity of number? No. Does it contain any experimental reasoning concerning matter of fact and existence? No. Commit it then to the flames: for it can contain nothing but sophistry and illusion!" (from Garrett by David Hume in An Inquiry Concerning Human Understanding).

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Fitness, apparently, consists in the ability of the organism to maintain the numerous internal equilibria as closely as possible to the resting state during strenuous exertion and to restore quickly after exercise any equilibria which have been disturbed (46).

It follows, then, that any of a variety of measurements made during heavy exertion may serve as an index of fitness, provided they show a wide enough spread between fit and unfit individuals and provided they are not easily influenced by extraneous factors such as emotions. It is well, also, to keep in mind that many persons are poorly endowed with cardiovascular and muscular systems and apparently cannot improve significantly in fitness (46).

Astrand (16, 17) and others (79, 91, 96, 131, 135) state that because heavy prolonged work depends upon the ability to deliver oxygen to the working muscles and since the rate of work depends upon the transport capacity of the heart, blood vessels and lungs, maximal oxygen consumption (hereafter termed MVO_2) has been shown to give the best available estimate of this type of physical fitness.

Tests with determinations of various factors during or after work of short duration provide one concept of an individual's ability for adaptation to work. If such work be increased to exhaustion, one obtains an estimate of the motivation of the individual and/or the maximal ability of the muscles to work under anaerobic conditions.

It may be presumed that the possibilities of determining the various

work intensities in a group of individuals, depend upon the working loads employed. One cannot expect to find any great differences in Physical Work Capacity (hereafter designated PWC) when using one or two rather light loads of work. However, with increased loads the discrepancies ought to be accentuated.

For a test of PWC, in the sense suggested, certain conditions are required. First, a large number of muscles should be involved so that the test will not give an estimate of the working capacity of muscles. Second, different and sufficiently heavy loads must be used to make it possible to estimate the MVO_2 level of each subject.

In order to accomplish such ends the bicycle ergometer seems to have distinct advantages. The following are a number of reasons why it is considered to be superior:

1. The bicycle ergometer takes up little space and is easy to handle.
2. The work can be reproduced easily and with a high degree of accuracy.
3. A large number of muscles are involved.
4. Oxygen consumption is directly related to work load.
5. It is thus possible to make a direct comparison between different subjects and between the reactions at different loads.
6. Various determinations are easily made during work.
7. Working intensity can be adjusted so that the subject is not overloaded.
8. The apparatus can be adjusted for younger and older and those with various pathologic states, e.g., cardiac, muscular dystrophy or asthmatic patients.
9. Adjustment for seat height and size allows for constant mechanical

efficiency for both trained and untrained subjects.

10. Results are comparable for a given individual under different conditions, between individuals and for different groups.

Whenever the testing of PWC of an individual is undertaken, the prime areas of concern are the cardio-circulatory and respiratory systems. In order to examine the functional ability of these systems, exercise physiologists agree that the human organism must be subjected to a prolonged form of heavy exercise which will allow observation of the systems under such conditions (16, 17, 79, 96, 131). As yet there is no such single test which has enjoyed general acceptance as an approximate measure of physical fitness (17). Indeed, quantitative assessment of physical fitness is one of the most complex and controversial problems in applied physiology.

A comparison of physical fitness as measured by MVO_2 and that measured by Kraus-Weber (87) yield quite different results. Obviously criteria for fitness play an important role in determining or establishing fit individuals as did the criteria which favoured the gymnastically-oriented European children in the Kraus-Weber test. As a result of the Kraus-Hirschland findings it is generally believed that North American youth is inferior to European youth with respect to physical fitness. The results astounded President Eisenhower to such an extent that he established a "Council On Youth Fitness", to work on the problem of youth fitness (133).

Since youth in Canada live essentially the same type of existence as the average American youth, the supposition was, then, that Canadian youth would perform along the same lines as the United States children.

The Duke of Edinburgh, in an address to the annual meeting of the Canadian Medical Association, in 1959, said (26:6) "It is estimated that 34% of the male population of military age are unfit for military service, in which case the prospects are not good if an emergency were to exist".

President Kennedy re-established the Conference on Youth Fitness only one month after his election to the presidency of the United States (3). In the article (3) he expressed his conviction that the physical condition of American people was an urgent national problem, demanding national action.

In order to promote the cause of youth physical fitness in Canada, the Government of Canada, equally concerned, established Bill C-131, the "Fitness and Amateur Sport Act", which was assented to, on the 20th of September, 1961. The objectives of the act are to encourage, promote and develop fitness and amateur sport in Canada. More specifically, the Act (29) states that it will:

1. "provide bursaries or fellowships to assist in the training of necessary personnel,
2. undertake or assist in research or surveys in respect of fitness,
3. arrange for national and regional conferences designed to promote and further the objects of this Act,
4. provide for the recognition of achievement in respect of fitness,
5. prepare and distribute information relating to fitness,
6. co-ordinate federal activities related to the encouragement, promotion and development of fitness,
7. undertake such other projects or programmes including the provision of services and facilities or the provision of assistance thereof,

in respect of fitness..."

The Problem

The primary purpose of this study then, is to establish, in so far as possible, norms for physical work capacity in a random sample of men at the University of Alberta on the bicycle ergometer. Work capacity will be determined by:

1. measuring maximal oxygen consumption,
2. measuring pulse response to fixed work loads.

Subsidiary Problems. A number of subsidiary problems will be considered in the present study namely:

1. a comparison of the results in this study to those of Rodahl, *et al* (108), from other countries, and
2. a comparison of the non-smoking and smoking subjects as to MVO_2 and maximal heart rate (hereafter MHR).

Limitations. This study is limited because of:

1. the number of subjects selected (N=100),
2. the possible experimental errors of the investigator,
3. the methods and instruments used in the study,
4. the statistical procedure used to analyze the data, and
5. the type of subjects selected (University of Alberta students 18-22 years).

Delimitations. The scope of this study is concerned only with the aforenamed variables, with regards to a specific sample of University of Alberta men ranging in age from 18-22 years.

Assumptions.

1. It is assumed that the modified Astrand maximal oxygen consump-

tion test does in fact measure maximal consumption.

2. Furthermore, it is assumed that when a subject fails to complete a work load due to exhaustion and is then rested and run through the test at a higher work load as described herein, he has in fact attained his maximal oxygen consumption.

Definitions.

1. Physical Work Capacity: The individual's total ability to perform prolonged physical work. This means the ability of the cardiocirculo-respiratory systems to take up, transport, and give off oxygen to the muscle tissues for performances of physical work (108). Physical fitness in this study will be used synonymously with the above-defined term.

2. Maximal Heart Rate: The exercise heart rate associated with the work level at which maximal consumption occurred.

3. Exhaustion: That physiological state of the individual, in which he could no longer perform the work at the prescribed revolutions per minute because of the inability of the physiological processes which maintain homeostasis.

4. Kilopondmeter (kpm): One kilopond is the force acting on the mass of 1 kilogram (kg) at normal acceleration of gravity. 100 kpm/min = 723 foot pounds 16.35 watts (111).

Abbreviations.

PWC physical work capacity

MVO_2 maximal oxygen uptake or consumption

VO_2 oxygen uptake or consumption

l/m liters per minute

bpm beats per minute

MHR maximum heart rate

ml/kg/min milliliters per kilogram per minute

$\bar{X}VO_2$ mean oxygen consumption

$\bar{X}HR$ mean heart rate

$\bar{X}MHR$ mean maximal heart rate

$\bar{X}MVO_2$ mean maximal oxygen consumption

CHAPTER II

REVIEW OF THE LITERATURE

The determination of MVO_2 has been of interest to investigation for the past fifty years. Some of the aspects studied in conjunction with MVO_2 are age, sex, body weight, and height, blood volume, and body surface area.

Little is known about the physiological functioning of the body at work. Most of what is known regarding physical performance capacity pertains to young males with little information regarding older men and women.

Numerous authors (23, 72, 78, 109, 111, 128, 130, 131) have established the fact that in any given individual there is a relationship between oxygen uptake and heart rate during maximal work. The slope of the line changes with the state of physical training or physical fitness, a fit person being able to transport the same amount of oxygen at a lower heart rate than an unfit person (109). This relationship is independent of sex and age (108).

During exercise, muscular activity creates an extra demand for oxygen. Man has no extra supply or store of oxygen. His blood carries the only reserve of this gas that there is in the body. The total quantity of oxygen carried in the blood amounts to about 1,300 cc. The basal requirements of an average adult are approximately 250 cc. per minute. During severe exertion this may be increased up to 30 times (58, 81, 97). Consequently, the body must be provided at all times with an abundant supply of oxygen if normal activity is to be maintained for some time. When muscle is exercised in the presence of oxygen, lactic

acid does not accumulate because the liberated lactic acid is oxidatively synthesized to glycogen during the process.

Exceedingly violent exercise cannot be maintained long because lactic acid and other products accumulate to maximal level and severe fatigue sets in after a certain amount of lactic acid accumulates. The muscles become incapable of performing under such circumstances. When the complete breakdown of homeostasis and the serious alteration of the physiochemical state has occurred the MVO_2 has also been reached giving an indication of the individual's PWC.

Maximal Oxygen Consumption

Various individuals (8, 10, 16, 17, 45, 72, 116) are of the opinion that during heavy prolonged work, maximal oxygen uptake is the best measure of physical fitness or work capacity. This (PWC) means the ability of the cardio-respiratory systems to take up, transport, and give off oxygen to the muscle tissues for the performance of physical work.

Mitchell, et al (96), believe that maximal oxygen intake is reached when oxygen intake per unit time has attained its maximum and remains constant owing to the limitations of the circulatory and respiratory systems. More specifically, when subjecting a normal individual to progressively increasing work loads, and allowing enough time for recovery between each increase of work, a linear relationship between work load and oxygen intake is found. Work load can be increased still further but ordinary oxygen consumption levels off or declines.

Andersen and Hart (8) found that in three-quarters of the subjects used, oxygen consumption levelled off at its maximum reading. The highest

MVO_2 reading in maximal work was 2.9 l/min with the group average being 2.5 in this study.

Astrand and associates (20) studied the effects of submaximal and maximal work on oxygen uptake, cardiac output, stroke volume, and oxygen content of arterial blood in twenty-three subjects ranging from 20-31 years of age. Studies were done at rest with the subjects sitting on a Krogh bicycle ergometer and during three or four submaximal and one maximal work load. The criteria for maximal load on the oxygen transporting system were levelling off of oxygen uptake and higher values for blood lactate concentration. Results obtained for maximal work load were 2.16 l/m for oxygen consumption in females while males had 4.12 l/m for MVO_2, which gives relatively high values for the male group if it was a normal average selection from the population.

Asmussen and Hemmingren (9) studied eleven normal subjects while walking on a treadmill and pedalling a tricycle with their arms. They endeavoured to see if the same maximal heart rate could be attained with arm-work as with leg-work, if the heart rate O_2-uptake relation was rectilinear with arm-work and noted the slope and origin of the heart rate O_2 uptake curve were different in arm-work from those of leg-work. Findings indicate that seven out of eleven subjects attained heart rates higher than 170 during work with the arms, while ten did so during work with the legs. All curves showed a similar rectilinear relationship between heart rate and O_2 uptake during arm-work and leg-work. Arm-work curves always had greater slopes than those for leg-work. The conclusion was that quite accurate estimates of the maximum capacity for arm-work can be deducted from submaximal work performances in the same way as for

leg-work by using their devised formula.

Astrand (16) determined the oxygen consumption for 115 males from 4 to 33 years of age and 112 females, from 4 to 25, in a series of experiments carried out on the treadmill and also on a bicycle ergometer for adults. He found that the MVO_2 was the same in both cycling and running, 4.03 and 4.04 l/m respectively, while the females attained a somewhat lower value during cycling as compared with running, 2.76 and 2.89 l/m respectively. This study demonstrates that very little difference exists in MVO_2 between cycling and running. The important factor to consider, Astrand (16:145) states, when testing for MVO_2:

> It shall be emphasized, however, that in testing the circulatory-respiratory fitness, a type of work must be chosen which engages great groups of muscles, and that the working intensity must be relatively high. The duration of the work must be relatively long to permit the adjustment of circulation and ventilation to the exercise, and the determinations have to be done particularly during the later stages of adaptation.

Saltin (111) studied 12 females and 20 males with regards to work time, size of the muscles involved and circulatory response during exercise up to maximal level. The subjects varied in physical fitness from individuals of sedentary living to athletes. In order to determine the importance of the muscle group size needed to attain the individual's maximal oxygen uptake the highest oxygen uptake value attained during cycling was compared with that attained during other types of muscular work. He found that MVO_2 during maximal cycling was not significantly different from the MVO_2 attained with cycling and cranking, running or skiing. Furthermore, he found no further increase in MVO_2 with combined arm and leg movements but did find that work could be carried on for twice as long a time than during leg work alone. From this study it was concluded

that aerobic work capacity could be determined during cycling work inducing exhaustion within two to eight minutes with a six minute load chosen as the maximum.

Astrand and Saltin (21) studied various types of muscular activities and secured the MVO_2 for each. It was noted that MVO_2 was greater in running uphill than simultaneous arm and leg work, cycling a bicycle ergometer in a sitting and supine position, running on a treadmill, skiing, swimming or cranking (arm work). The physiological reasoning behind the higher MVO_2 as a result of running uphill is not clearly explained by the authors but, as is known, a greater muscle mass creates greater oxygen consumption and this could possibly be one explanation for the difference.

Astrand and Saltin (22) studied one female and four male subjects in regard to very heavy exercise on a bicycle ergometer. The subjects pedalled a frequency of 50 revolutions per minute for 2 to 8 minute periods depending upon work intensity. From the 42 observations made they noted that exhaustion was brought about within 8 minutes of work, and the highest MVO_2 recorded was 5.30 l/m. It was also observed that the time it took to establish a plateau for oxygen uptake during exercise depends upon the work load. After a 10 minute period of warming up, about 2 minutes of very hard exercise is, for young, healthy and well-trained individuals, sufficient to adjust the oxygen transporting system so that maximal oxygen uptake and heart rate are attained. This conforms with the ideas of both Mitchell _et al_ (96) and Taylor _et al_ (131). Astrand and Saltin (22) go on to state further that, (22:274): "Although the concentration of lactic acid in the blood is about the same in a 2-minute exhausting exercise as in a 7-minute one, the concentration within the

working muscle is probably different at the end of work, even though oxygen uptake and heart rate are similar in the two experiments". They concluded that when respiratory and circulatory functions are measured during lighter muscular exercise, duration of work should be at least 5 minutes because it may take this time for an adaptation. Only with extremely heavy exercise do measurements after 1 minute reveal the apparent steady state values, with a warming-up period preceding the heavy work.

Establishment of criteria for MVO_2 seems to be a subject which has yet to be settled. Taylor, et al (131) are of the opinion, if two consecutive readings are separated by a grade of 2.5% and differ by less than 150cc/m, that there is a small chance of making an error in deciding that the MVO_2 had been reached. Mitchell, et al (96), on the other hand, used 0.0531 l/m, while Astrand (116) used 80 ml/m as the criterion difference for distinguishing whether the MVO_2 was reached or not. Wyndham and associates (141) examined the best fitting curves of oxygen intake plotted against work rate and found the curves approached their asymptote slowly. As a result of the slow asymptote, the authors recognize that no simple criterion to define the MVO_2 is at hand, consequently making it difficult to be entirely positive. Relative to some of Wyndham's opinions, Schneider (113) found that oxygen consumption varies almost directly with the amount of work done in the same unit of time. It was also found that with moderate loads of work the adding of equal increments to the load results in approximately equal increments in the absorption of oxygen. Furthermore his findings reveal that once the individual surpasses his crestload and is engaged in overload the linear

relationship between work load and oxygen consumption is broken down.

Hettinger and colleagues (72) studied 96 policemen and found that in all cases a definite plateau of the oxygen uptake was obtained as the work load was increased, indicating that the MVO_2 was being measured and also indicating the same findings that Wyndham had observed.

Buskirk and Taylor (34) conducted an interesting study on the relationship between MVO_2 and obesity in relatively inactive subjects. The subjects were divided into three groups: less than 10% fat, 10-25% fat and greater than 25% fat. Comparison of the groups was made by using a one-way analysis of variance and no difference between the groups could be detected. The conclusion drawn was that the presence of excess fat does not have any important influence on the capacity of the cardio-vascular and respiratory systems to deliver oxygen to the muscles under maximal performance. However, obese men are under a substantial handicap in physical performance requiring exhaustion work because of the load of fat which they must carry with them.

As was cited previously in this study various individuals are of the opinion that, at the present time maximal oxygen consumption is the best available measure of PWC. The criteria currently used for determining MVO_2 is when the difference between two readings does not exceed more than 150cc/m at the maximal level. In order to measure MVO_2 one must be sure that large muscle groups are involved and that the work intensities are great enough to produce exhaustion within the individual.

Validity and Reliability

Hettinger, et al (72), compared the MVO_2 and the results of various

physical fitness tests in 96 men ranging in age from 23-62 years. The MVO_2 was determined in series of experiments using a bicycle ergometer with a pedal frequency of 50 rpm, each work period lasting 3-5 minutes. Findings showed no statistically significant correlation between the maximal oxygen uptake and the Leistungs-Pulsindex (LPI). The correlation between the MVO_2 and Master Step Test, Amplituden Puls-Frequenz (APF) and Harvard Step Test, is significant at the .05 level, .02 level, .001 level and .001 level of confidence respectively.

The reliability of MVO_2 was found to be .95 by Taylor, et al (131) and .97 by Linderholm (cited in 30). Even though the tests by the above authors were carried out using different techniques in both cases, the reliability of a MVO_2 test is shown to be very high, thus indicating its reproductability to be very good. Borg and Dahlstrom (30) tested the working capacity of 78 forest workers on the cycle ergometer during a period of military training. The test was carried out on successively increased power levels and for a period of 6 minutes for each level, 600, 900, 1200 kpm/m. The pulse frequency was determined after working periods of 2, 4, and 6 minutes and the breathing frequency after 3 and 5 minutes for each level. The test-retest for this study was affected by the long delay in the retest, since PWC of some individuals increased while for others it decreased. In order to obtain a measure of the intra-test consistency, reliability coefficients were assessed between the pulse rates at 2, 4, and 6 minute periods of work. Several test-retest correlations were also calculated from most of the measurements in both tests. Findings showed that the highest intra-test correlations were observed, between the pulse rates from 4 to 6 minutes, and between the 1st and 2nd

tests (r=0.98) for 900 kpm/m. The corresponding correlations for the 600 kpm/m level were r=0.90 and r=0.60 for the 600 and r=0.60 and r=0.70 for the 900 kpm/m levels.

The test-retest correlations for PWC_{170} values from the 6 minute assessments were as high as r=0.76. The Astrand values for the higher level on both occasions correlated r=0.71, with the average for both work levels being r=0.67.

The validity correlations revealed a fairly good relationship between several test measurements and the criterion. The correlations between the pulse rates from 6 minutes' work at 900 kpm/m in the 1st and 2nd tests were r=0.35 and r=0.51 respectively. The corresponding correlations between the criteria and PWC_{170} values were r=0.35 and r=0.54, and between the criterion and the Astrand test from the highest level r=0.38 and r=0.45.

Saltin (111) studied 32 subjects who varied in physical fitness from sedentary individuals to athletes. He found the standard deviation of maximal oxygen consumption to be 3.1% which included both the biological and methodological variables, with a standard deviation of heart rate of three beats per minute.

Glassford (67) studied the relationship between values of MVO_2 in various MVO_2 tests and also the Johnson, Brouha and Darling physical fitness tests. The results are shown in Table 1.

All correlations were found to be significantly different from zero beyond the .01 level of confidence.

Astrand and co-workers (13) re-tested individuals 4 years later and obtained almost identical MVO_2 results to those of the first test, once

again indicating the reliability of MVO_2 testing.

TABLE I

CORRELATION COEFFICIENTS OBTAINED BETWEEN THE FOUR MAXIMAL OXYGEN CONSUMPTION TESTS AND JOHNSON, BROUHA, AND DARLING FITNESS SCORES

(Milliliters per minute per kilogram of body weight)

	M S C	T B H	A A	A P
J B D	.63	.65	.65	.79
M S C		.68	.65	.77
T B H			.74	.62
A A				.63

J B D - Johnson, Brouha and Darling Physical Fitness Test.

M S C - Mitchell, Sproule and Chapman Maximal Oxygen Intake Test.

T B H - Taylor, Buskirk and Henschel Treadmill Test of Maximal Oxygen Consumption.

A A - Modified Astrand Bicycle Ergometer Test of Maximal Oxygen Uptake.

A P - Modified Astrand-Rhyming Nomogram for the Prediction of Maximal Oxygen Uptake.

Baycroft (27) studied 48 physically active males ranging in ages 17 to 35 in an attempt to evaluate the modified Astrand-Rhyming nomogram (predicted test) as an estimator of oxygen consumption, as measured by the Mitchell, Sproule and Chapman MVO_2 Test, and the Modified Astrand Bicycle Ergometer Test of MVO_2. The oxygen consumption values were also correlated with height, weight and body surface area as well as the fitness score and time run on the Johnson, Brouha and Darling Test of Physical

Fitness.

The investigator found that the modified Astrand-Rhyming nomogram produced significant correlations ($p = .01$) of 0.67 with the Mitchell, Sproule and Chapman Test and 0.62 with the modified Astrand Bicycle Test. The Mitchell, Sproule and Chapman Treadmill Test correlated 0.51 with the maximal bicycle ergometer test. With body weight partialled out, correlations were again significant ($p = .01$) and equal to 0.53, 0.47, and 0.39 respectively.

Fitness as scored by the Johnson, Brouha and Darling Test produced significant correlations ($p = .01$) of 0.38 with the Mitchell, Sproule and Chapman Test, 0.46 with the bicycle test, and 0.55 with the predicted test in terms of liters per minute. Corresponding values for milliliters per kilogram body weight per minute were 0.46, 0.55, and 0.67 respectively.

Height correlated significantly with the Astrand Maximal Bicycle Test, Mitchell, Sproule and Chapman Test, and the nomogram predictive test ($p =$ .01, .05, and .05 respectively) in terms of liters per minute.

It was concluded, according to the group studied, that the Mitchell, Sproule and Chapman Test and the Modified Predicted Astrand Rhyming Nomogram for MVO_2 yielded significantly higher mean values than the Modified Astrand Ergometer test of MVO_2. Also, statistically equivalent means were obtained on the modified Astrand-Rhyming nomogram and the Mitchell, Sproule and Chapman Test. Furthermore, he concluded that greater significant variance was produced by the Astrand-Rhyming nomogram than by the Astrand Bicycle Ergometer Test and the Mitchell, Sproule and Chapman Test.

Astrand (16) found the correlation between MVO_2 and body weight

to be 0.98 for males, for girls below 40 kg, 0.96, and for females over 40 kg, 0.86. When comparing the body weight correlations of both Astrand (16) and Baycroft (27) one finds a fairly large difference. It is not known why such a discrepancy is shown, but Astrand used many more subjects.

The review of literature herein indicates that, when comparing the reliability and validity of the bicycle ergometer with other tests measuring MVO_2 and MHR, it compares very favourably. This would then seem to indicate that the MVO_2 and MHR tests are both very reliable and valid as components for the PWC test.

Factors That Influence MVO_2 and MHR

Effects of Age on Maximal Oxygen Consumption and Heart Rate

Hettinger, et al (72), found that the mean MVO_2 of 2.22 l/m on 96 policemen was no higher than that of nine well-trained 46-68 year old men. In this same group of policemen nine men with a mean age of 30 years were studied and the mean maximal oxygen consumption was 2.53 l/m, which was only .31 ml higher than that of the 56-68 year old men.

Dill (51) observed himself a number of times when performing the Balke Treadmill Test to note the effects of age. He first took the test in 1957 at an age of 66 and he was then tested again at ages 68 and 70. Observations illustrated that his maximal VO_2 was 2.80 l/m with a heart rate of 160 at the age of 66, 2.55 and 156 at age 68 and 2.20 l/m and heart rate of 151 at the age of 70. Whether Dill himself belongs to the elite (re physical fitness) of the older generation or not was not specified but, such would seem to be the case with his relatively high

MVO_2's.

Durnin and Mikulicic (55) studied the influence of graded exercises on the oxygen consumption, pulmonary ventilation and heart rate of young and elderly men. Findings indicated for exercise of the arm ergometer and a treadmill at speeds of 3.7 (T_1) and 4.3 (T_2) mph., that the mean values for oxygen consumption of the elderly were higher than those of the young men. The difference between the two groups, while doing the ergometer exercises, was not statistically significant, whereas, the differences between the elderly and the young were highly significant, $P<0.01$ for treadmill T_2.

Strandell (124), using 121 healthy men aged 30-83 years, studied heart rate, oxygen uptake, arterial lactate and pyruvate concentrations during stepwise increased workloads on a bicycle ergometer. He found that the oxygen consumption of 24 subjects in the age group 60-83 years increased from $.97 \pm 0.11$ at 900 kpm which seems to correspond to subjects in the age range 18-22 years as found in this work. Furthermore the older men did not increase more rapidly than the younger men. Strandell is of the opinion that from 30 to 60 years of age the mean decline in the MVO_2 in men amounts to approximately 25-30 per cent. He also found that maximal heart rate in the upright position declined from a mean value of 190-195 beats per minute at 20 years to around 160-165 beats per minute at 60 years of age. It was also observed that older men had a higher lactate and an increase in recovery time and removal of CO_2 than younger men but, in submaximal tests, the heart rate and oxygen consumption were similar.

Durnin and Mikulicic (55) reported that there was no significant

difference in heart rate with the arm ergometer between the elderly and the young in any of the four different periods analyzed (first 3 minutes of exercise, first 2 minutes of recovery, then 7 minutes of recovery). With the treadmill ($P<0.05$ for T_1 and T_2) there is a difference for the first 3 minutes of exercise and also for the 3rd to the 10th minute of recovery in the second degree on the treadmill ($P<0.05$). After the second treadmill run (T_2) at 4.3 mph the recovery rate of the elderly men from the 3rd to the 10th minute was slower.

Strandell (125) studied heart rate and work load at maximal working intensity during stepwise increased work loads on a bicycle ergometer in the sitting and supine position and during combined arm and leg work in 27 healthy men aged 61-83 years. Maximal heart rate in the sitting position decreased with age from 166 beats/m in the 60-69 group to 139 beats/m in the 80-83 year old group. Maximal work decreased simultaneously and maximal work or heart rate did not increase significantly when the tests were repeated. During combined arm-leg work, both maximal heart rate and work were significantly higher than during leg work alone. Saltin (111) also found that as a result of both arm and leg work, the actual leg work could be carried on twice as long as work with arms or legs alone.

Strandell (125) also found that the mean MVO_2 decreased with age from 2.27 l/m in the 60-69 year group to 1.99 and 1.50 l/m in the 70-75 and 80-83 year group.

Astrand (12) investigated 81 subjects with respect to physical work capacity, of whom 46 were 50-54, 27 were 55-59, and 8 were 60-68 years old. All were truck drivers and had been employed in the same type

of work for an average of 21.2 years. All subjects were tested on the bicycle ergometer until exhaustion. The investigator found that the average maximal heart rate in 45 subjects 50-64 years old was 161 beat/min. while for 22 subjects 55-59 years it was 158 and for 6 subjects 60-64 years old 158 beats/minute. The average maximal oxygen intake for the three age groups was 2.55, 2.43 and 2.14 l/m respectively. From the above results it is easy to note the decrease in the maximal values that the older group attain and as the subjects get older the decrease in both heart rates and MVO_2 are shown.

Dill, et al (54), studied the work capacity of 7 subjects ranging in age from 54 to 71 at sea level and altitude and compared some results to measurements taken from 18 to 33 years earlier. The observations showed that work capacity decreased with increasing age.

Norris and Shock (102) cited a study done by Valentin and associates giving values for average MVO_2 in normal subjects between 12 and 80 years of age when using a crank ergometer. The workload was set by asking the subject to perform at successive workloads which increased by increments of 30 watts (30, 60, 90, etc.). On another day, the highest work rate which could be maintained for two minutes was performed and the measurements of oxygen uptake were made. Mean values were obtained for the subjects in the 12 to 19 age range, the 20 to 40 age range, and for 30 subjects in each of the 10 year age spans up through 80 years of age. The mean maximum oxygen uptake increased from 1.86 l/m in the 12 and 13 year old group to a maximum of 3.02 l/m in the 18 and 19 and 20 to 40 year old group. It then decreased uniformly to 1.60 l/m in the 70 to 80 year old group. Heart rates followed the same pattern, decreasing from

a maximum of 200 beats per minute at 20 years of age to about 140 beats a minute at around 70 years of age. Similar results were also obtained by Robinson (107) in his 1938 study.

The oxygen consumption had been determined by Astrand (16) for 115 males (from 4 to 33 years of age) and 112 females (from 4 to 45) in a series of experiments carried out on the treadmill and on the bicycle ergometer. The subjects worked to a state of exhaustion, working time about 5 minutes. Findings showed that for males the average MVO_2 values increased from 1.0 liter per minute to 2.0 to 2.5 to 4.1 l/m for boys aged 4-6, 10-11, 12-13 and for adults respectively. The average value for the girls up to the age of 12 is 2.43 and for girls 14-15 years and older the mean value was 3.78 l/m. In both males and females, MVO_2 increases with age and is fairly linear up to the age of 13, but after that, the relationship breaks down. The increase in oxygen intake is relatively greater, the greater the respective height and surface area. Several investigators (16, 17, 27) have found that MVO_2 increased roughly linearly with increasing body weight for male subjects.

Robinson (107) studied his subjects on a treadmill at 2 different intensities. He found that for 25 year olds the highest oxygen intake was 53 ml/kgm body wt/min. The 40 year olds reached 82% or 41 ml/kgm body wt/min, 50 year olds 78% or 39 ml/kgm body wt/min, 60 year olds 70% or 35 ml/kgm body wt/min and 70 year olds 60% or 30 ml/kgm body wt/min.

Comparing the results of Astrand (16) to those of Robinson (107) it was found that those of Astrand were of a higher VO_2. This could have been attributed to a number of reasons, such as working intensities,

work test procedures and physical condition of respective subjects. The comparison of the groups themselves (in some cases) is not a good one and could be criticized on that basis alone. Results conflicted when the groups were compared during the period of puberty in which Astrand found no decrease in MVO_2 whereas Robinson did.

Astrand (16) determined heart rates during maximal running and cycling in 115 male subjects aged 4 to 33, and 112 females aged 4 to 25 years. No differences between maximal values obtained during cycling and running were found. Observations indicate that for subjects below 20 years of age, and for adults, the mean values obtained were 194 for men and 198 for women. It was also noted that, excluding the youngest subjects, there were no indications of a decreased stroke volume with increasing heart rate, not even at the highest rates. Robinson (107), using subjects aged 6-30 years, found that the maximal heart rates fell in between 190-200 beats/min and that the values of older individuals were consistently lower, 40 year olds being 183, 55 year olds, 168 and 70 year olds, 160.

Astrand (10) studied 44 female subjects between 20 to 65 years old with regards to aerobic work capacity. The subjects were broken down into 4 groups: 8 subjects in the 20-29 group, 12 in the 30-38, 8 in the 40-49 and 16 in the 50-65 year old group respectively. The 20-29 year old group had the highest MVO_2, 2.23 l/m, with it decreasing to 1.85 l/m for the 50-65 year old group. Maximal recorded heart rates were found in the youngest group to be 187 and the lowest was found to be 170 in the oldest group. Thus we see the parallel between male and female of the effects of age on the previously discussed phenomena.

These results (10) were compared to Astrand's (16) results and a MVO_2 difference of 23% was noted in favour of the 1952 results, which is significant at the .001 level of confidence. The decrease of MVO_2 from the youngest to the oldest in this study (10) was found to be in the neighbourhood of 17%. It was concluded that the MVO_2 difference is dependent upon both the inherited physical traits with respect to the circulatory parameters and different degree of physical training.

I. Astrand (11), in her clinical and physiological studies of manual workers 50-64 years of age, found that when both older and younger subjects performed maximal work they complained about local muscle fatigue as the most troublesome factor. Astrand (16) believes that the blood supply in younger subjects is insufficient, causing muscular pain. Astrand (11) also found that in older subjects there was a much lower heart rate, oxygen intake, pulmonary ventilation and lactic acid concentration than in younger people.

Cullumbine and associates (42) studied the influence of age, sex and physique and muscular development on physical fitness. It was observed that the fitness index for 5 minutes of moderate exercise, the endurance index, and severe exercise decrease with age. Speed, strength and the ability to sustain moderate effort to exhaustion all increase with age, to reach maxima in early manhood or womanhood.

Fowler and Gardner (63), in a study of the relationship of a cardiovascular test to measurements of motor performance and skills, found that PWC increased with age for both sexes up to the age of 14, after which with girls it started to decrease. These results are in agreement with other authors (2, 16).

Studying the responses to exercises as related to age and environmental temperature, Dill and Consolazio (52) worked with the same subjects after a time lapse of 29 years. Results indicated that while exercising on the treadmill the oxygen consumption of one subject declined 31% from 1933 to 1961 while the other had a decline of 17%. Corresponding values at a given age for oxygen consumption in exhausting work on the ergometer were from 10 to 20% lower than on the treadmill. Maximal heart rate declined much less with age than MVO_2. The authors believed that this proved, in maximal work, that there is a decrease with age in oxygen transport per beat. In all-out work performed on the ergometer oxygen transport was 17 ml per beat in 1932 and 14 in 1961.

When comparing heart rates, each subject showed little change in heart rate in easy and moderate work at temperatures of 30°C and lower.

Cumming and Cumming (44) studied the working capacity of normal children tested on a bicycle ergometer in Winnipeg, Canada. One hundred and twenty-five subjects ranging in ages 6-16 in 10 city schools were selected. They exercised on a bicycle ergometer for 4 consecutive six minute periods pedalling at 60-70 revolutions per minute. All subjects reached a maximum heart rate of 170 beats per minute, which was the criteria. They found a gradual rise in maximal work capacity (MWC) with increasing age. It was also observed that the MWC of 15 and 16 year old girls was greater than nurses and that 16 year old boys and medical students had approximately the same level of performance. Although numerous reasons exist for the PWC performance being similar in the above mentioned case, probably the most dominant reason for the similarity in PWC is the state of physical fitness.

Cumming and Danzinger (45) conducted a study on the validity of the pulse rate method in determining work capacity as being dependent on linear relationship between oxygen consumption and pulse rate. Forty-two students in grade five, ranging in ages 10 to 11 years, were subjects. Each individual exercised on an electronically braked bicycle ergometer, for 2 successive 6 minute work periods, and the work load at an anticipated minute pulse rate of 170 was determined by extrapolation of previous tests on the subjects. In addition, 24 subjects were also selected for oxygen consumption studies in which the electrocardiogram was used during exercise. The subjects pedalled at 60 to 70 revolutions per minute until maximum heart rate was reached. Maximal VO_2 was measured simultaneously with maximal heart rate, with the expired air being collected during the last 2 minutes of work. Observations showed no significant difference between a test in May and September of the same year in either males or females. The highest pulse rate recorded was 215. For submaximal work loads, pulse rate was usually constant from the second to the sixth minute of each exercise period, and it was only when near maximal work load was reached that a rise of over 8 beats per minute was observed. During maximal work loads there was a progressive rise in pulse rate until the subject gave in to the feeling of exhaustion.

Kramer and Lurie (86) worked on maximal exercise tests in children. Observations showed that untrained normal boys had mean MVO_2's comparable to those reported by Robinson in the 1938 Boston Study and Morse, et al, in a 1948 Chicago study, higher than Reindall, et al, in a 1959 Freidburg, German study, and Rodahl, et al, in a 1961 Philadelphia study and lower than by Astrand (16) in a 1952 Stockholm study.

When the mean maximal exercise heart rate was studied it was found to be 191 in average normal boys aged 9 to 16 years. This result was comparable to values in normal boys previously reported in the literature which are: 190 by Boas in 1931 for boys aged 9 to 15 years, 196 by Dill and Brouha in 1937 for boys aged 12 to 19 years, 195 by Robinson in 1938 for boys aged 6 to 19 years, 196 by Morse, et al, in 1948 for boys aged 9½ to 17½ years and 205 by Astrand in 1952 for boys aged 10 to 18 years. The subjects of both Boas and Kramer and Lurie (86) were not run to exhaustion as other subjects were, and therefore the highest heart rates were not attained.

Bengtsson (28) determined the PWC in normal children by a submaximal exercise test on the bicycle ergometer and compared them with adults. His results showed that PWC in relation to age was not very pronounced in adults and that it was often lower in the older than in the younger adults. Subjects aged 15-20 had working capacity between that of children and that of adults who were physically in their prime. The most pronounced variations due to age were found in children. Shock (117:656) states:

> From the evidence now available, it is apparent that loss of protoplasm is an important factor in the age decrement in performance capacities of the total animal. Thus far, the largest age decrements have been observed in cellular functions are no greater than 10 to 15 per cent, in contrast to decrements of 40 to 60 per cent, in total organ performance. For the present it must be assumed that a gradual loss of functioning tissue makes a major contribution to age impairments.

In the literature contained herein one finds that age does have a definite effect upon both MVO_2 and MHR. The review showed that both MVO_2 and MHR increased up to the age of 30 years old in both males and females but after this age the MVO_2 and MHR decreased with age. The

consensus of the literature is that the MVO_2 and MHR were highest in the 20 to 30 year old group.

Effects of Sex on MVO_2 and Heart Rates

Astrand (16) carried out numerous studies on PWC in relation to sex and age. In particular he studied heart rates during maximal running and cycling in males and females and found for subjects below 20 years of age, that the average values lay between 202 and 211 and were independent of age and sex, whereas for adults the mean values obtained were 194 for men and 198 for women. In this same study MVO_2 was determined for both males and females. Findings showed that the average values of the girls up to the age of 12 were 13 to 17% lower than those of the boys of the same age. For girls 14-15 years and older the means were 26-29% lower than for males. The mean MVO_2 for males was the same in both cycling and running while females attained lower values during cycling as compared with running.

In his review of human physical fitness with special reference to sex and age, Astrand (17) reported a number of observations. He found approximately the same MVO_2 per kilogram body weight for 4 to 9 year old girls and boys. For subjects somewhat older than 12 years the oxygen intake per kilogram body weight was less in females and reached values (46-48 ml/kg/m) about 17% lower than those of males. For adults the maximal oxygen intake averaged 4.11 l/m for 42 men and 2.90 l/m for 44 women, about 29% lower. Pulse rates for males and females were approximately the same during maximal work, whereas for submaximal work females had a pulse rate considerably greater than men.

Cullumbine (42), when studying the influence of age, sex, physique and muscular development on physical fitness, found that females did poorer in all the measurements that were taken.

The maximal working capacity for the two sexes and for different age groups from 4 to 30 years was determined by Astrand (18). He studied 117 males and 110 females and found a definite sex difference between male and female adults with women scoring 30% lower than males. No MVO_2 sex differences in children were found before puberty, but after puberty girls were once again 20% lower than boys. Children below 7 years of age were found to have the same oxygen intake per kg body weight as grown-up women, and children between 7-12 years had an oxygen consumption of 5-10% lower than adult men. Bengtsson (28) had similar findings. He found that the work capacity of women was 30% lower than adult males. Although most girls of advanced school age (15-20 years old) were bigger and of heavier build than boys of similar age, the work capacity of boys was distinctly higher.

Fowler and Gardner (63), in their study of the relation of cardiovascular tests to measurements of motor performance and skills, obtained results similar to the literature previously reported. More specifically, physical work capacity increased with age in both sexes, but boys were superior to girls even at the earlier ages with sex differences becoming greater as growth proceeded. The rapid increase in size between 13 and 14 years of age in males was paralleled by a sharp increase in working capacity at age 14. Girls failed to show this sudden increase and the mean working capacity actually decreased at age 14.

Brouha (31) worked on the physiology of training, including age and

sex differences. Observations showed that at a given level of oxygen consumptions the heart rate was higher in women than in men, and conversely, for a given heart rate, men could transport more oxygen than women during submaximal and maximal work. Even though the average aerobic capacity was 25 to 30% lower in women, both sexes were found to utilize their anaerobic processes to the same degree.

Metheny, et al (95), studied seventeen women between 20 to 27 years of age and 30 men between the ages of 19 and 23 years. The subjects were exercised on a treadmill at 3.5 miles per hour at 8% grade (the walk) and at 7 miles per hour they were exercised strenuously (the run) on the same grade for five minutes of work until unable to continue. Results indicated that for the walk, all subjects performed the same amount of work for the same length of time and they all reached an approximately steady state within the first 5 or 6 minutes. There was no marked difference between men and women in oxygen consumption and recovery heart rates were approximately the same. The women had a higher concentration of lactate and a more rapid increase in heart rate and also reached a higher maximum.

During the run, the women ran half the time the men did, maximum pulse rate was approximately equal for the two groups, maximum lactate concentration was roughly equal for both, women had a higher sugar level after the run, and men had a greater R.Q., ventilation and maximum oxygen consumption.

The authors concluded that it was evident that this exertion was more strenuous for the women than for the men, taxing all the body systems to their limits in a much shorter time.

Astrand, et al (20), studied 23 subjects ranging in ages 20-31 on a Krogh bicycle ergometer. Studies were done with the subjects sitting on the Krogh bicycle ergometer and during 3 or 4 submaximal and one maximal work load. Criteria for maximal load on the oxygen transporting system were the leveling off of oxygen uptake, and high values for blood lactate concentration. Results obtained for the maximal work load were 2.61 l/m oxygen consumption and 189 maximal heart rate for females while males had 4.12 l/m oxygen consumption and a maximal heart rate of 185. Average cardiac output was lower for women than men (18.5:24.1).

In both sexes the maximum heart rate during exercise was related linearly with increasing work load, but exhaustion was reached at a lower level of performance in women. Linde (91), in his article on exercise fitness tests, made some broad generalizations. He is of the opinion that at all ages females need higher pulse rate than males to transport the same amount of oxygen or to expend the same amount of energy. Furthermore, he believes that sex differences regarding PWC are evident from early childhood and increase in magnitude with growth and development.

The effects of sex upon the physiological parameters of MHR and MVO_2 is clearly shown in the review presented herein. Generally, it can be said that the MVO_2 of women was substantially lower than in the men and the MHR was similar to that of the men. However, it was also found that in extremely exhaustive tests, exertion was more strenuous for women than for men. Therefore one could surmise this indicated that strenuous exercise taxed all the body systems of females to their limits in a much shorter time.

Effect of Environment on MVO_2 and Heart Rates

Scientists and laymen alike have long recognized that the environment of a worker has a significant effect on his ability to do mechanical work. The components of the environment having the greatest influence on man's ability to perform are those which directly affect his heat loss or gain. The limiting effect of the environment applies most directly to the ability of the individual to expend mechanical energy continuously at a given rate. Suggs and Splinter (126) believe that several components of the environment affect the loss of excess heat from an animal body. They feel the most important of these are dry-bulb temperature, relative humidity or wet-bulb temperature, thermal radiation and air velocity.

Unfavourable environments, especially hot, humid conditions and high mean radiant temperatures impose a physiological load on an individual which is just as real and in many cases larger than that of the work load he performs (126). If total physiological load or strain is not to exceed optimum limits then work loads must be decreased whenever environmental load increases.

While studying the effect of environment on the allowable work load of man, Suggs and Splinter (126), found that when environmental temperature was raised from 88°F to 158°F the heart rate increased 8 to 9 beats per minute above those values taken at 88°F whether working on the bicycle ergometer or not.

Consolazio and associates (39) observed that men working and living in extreme heat increased caloric intake. This increase was attributed directly to the increase in energy cost to perform various resting and exercising activities. In another study of environmental temperatures

and energy expenditures, Consolazio, et al (38), corroborated the above results and attributed the increase in metabolism and energy requirements to the heat of the environment.

Brouha and co-workers (32) found that oxygen consumption increased with the onset of exercise, remained at relatively steady levels during sub-maximal work, then, when maximal load was imposed, underwent further increases which were both rapid and progressive. With the cessation of exercise, oxygen consumption decreased sharply at first, then gradually. Results of temperatures and environmental changes showed that a warm-dry environment induced the most persistent effect which was a highly significant (at the 1% level) decrease in oxygen consumption during work and recovery. Minimal heart rates for work and recovery were recorded when work was done at normal temperatures and maximal rates in the warm-humid environment. Heart rate also showed a tendency to be higher in the warm-dry environment than in the normal one. Heart rate during submaximal work regardless of ambient conditions showed a progressive increase regardless of one constant work load. The authors also found that oxygen consumption returned to its resting level at the same rate regardless of environment, whereas the cardiac recovery was much slower in the warm surroundings.

Dill and Consolazio (52) studied the responses of exercise as related to age and environmental temperature on two elderly subjects. When observing the effects of temperature on heart rate in subject DBD, while performing easy and moderate work at 40°C, it was noted that the 1962 heart rate was slightly above that of the 1933 rate and was much higher at 50°C. For subject FC heart rates were about the same as in 1939 in all grades of work at temperatures of 0°, 10°, and 20°C. They were lower for 30° and

40°C in 1961 and at 50°C in 1961 they were higher than in previous easy work and about the same in moderate and hard work.

Saltin (111) studied aerobic work capacity and circulation during exercise in man with special reference to the effect of prolonged exercise and/or heat exposure. He studied a group of subjects composed of 6 females and 50 males with the degree of training varying from champion skiers to sedentary types. Observations indicate that for submaximal work no definite difference could be demonstrated in oxygen uptake during submaximal work before and after exercise and heat exposure. However, there was a tendency toward a small increase in oxygen uptake when the test work took place after exercise dehydration as a result of body heat. After both types of dehydration as a result of exercise, heat and thermal heat, the heart rate was, in submaximal work, significantly higher than before the heat built up. It is interesting to note that higher heart rates were recorded after exercise than after thermal heat and dehydration.

In maximal work, measurements of oxygen uptake and heart rate gave almost identical results under normal conditions and after thermal dehydration. However, work time at the maximal load was significantly reduced after both thermal and exercise dehydration, with a significantly larger reduction after exercise rather than thermal dehydration.

Saltin (111) found that both well-trained and untrained subjects exhibited a gradual decrease in work capacity during heat build-up or exposure. He feels as others do (126) that the greater the part played by metabolic heat as a stress factor, the more extreme is the decrease in work capacity. Saltin expresses the opinion that excess lactate, being higher in a hot environment, may be considered proof that the blood flow

to the muscles is lower during work in a hot environment than in a colder one. This may be a reason for a decrease in work time in hot environments and also the reason for faster increase in heart rate per minute during exposure to hot environments. He also implied that decrease in physical work capacity during dehydration, as a result of exercise and thermal heat, was due not to reduced aerobic work capacity but that an explanation should be sought at the cellular level, where changes occur during the dehydration process.

Rowell, Taylor and Wang (132) studied non-athletic young men in temperatures of 62°F, 78°F and 100°F. No acclimatization to high temperatures was carried out by any of the subjects. Observations showed that no difference in MVO_2 was found between 62° and 78°F, while the decrease at 110°F was of the magnitude of 6%, agreeing with the findings of Brouha, et al (32), and others (38, 39, 52).

Lablanc (88) observed from his study that ambient temperature will modify the linear relationship that exists between heart rate and oxygen consumption. He illustrated that for all levels of activity, the heart rate is lower at lower temperatures (40° to 70°F), but if temperature is increased from 70° to 80°F, the increase in pulse rate is relatively larger than the one observed for a similar change in the (40° to 70°F) for the lower levels of activity. It is at the 70° to 80°F increase that the heart rate departs from the linear relationship with oxygen consumption. As a result of his latter observation he concluded that in warm environments heart rate was more informative than oxygen consumption of the strain or fatigue experienced.

The literature pointed out that dry-bulb temperature, wet-bulb

temperature, thermal radiation and air velocity are factors that decrease the PWC of individuals. It was also stated that heart rate increased in warmer temperatures regardless of whether the individual did any work or not. Oxygen consumption returned to normal in a warm environment as easily as it did in a normal environment, but cardiac recovery was much slower in the warm surroundings. Generally, the studies observed that the subjects exhibited a gradual decrease in work capacity during heat exposure and also that the heart rate per minute increased when the temperature was above 80°F. Other observations indicated that heart rate rather than oxygen consumption was more indicative of strain or fatigue in warm environments.

Mechanical Efficiency on the Bicycle Ergometer

It must be borne in mind that mechanical efficiency varies because of numerous factors such as speed, the external work load, the training of the subjects, the duration of the work period, diet and the base lines used in determining the net efficiency.

In simple movements, where large muscle groups are working, it has been found that the mechanical efficiency shows only small individual variations (17).

Wahlund (135) found that during work on the bicycle ergometer the standard variation in mechanical efficiency was 8% of the established values for athletes, normal healthy men and people with heart or respiratory troubles, provided the work was adapted to the capacity of the individual.

Men and women have roughly the same mechanical efficiency during cycling, according to Astrand (16). He also believes (17) that an

improvement in mechanical efficiency usually results from training, among other things. Astrand states (17:316) that:

> ... mechanical efficiency of muscular work depends upon whether carbohydrates or fat is consumed. The efficiency is lowered when there is a high fat combustion. At a given work level the speed of movements can influence the work economy.

Suggs and Splinter (127) found that mechanical efficiency was significantly affected by temperature, relative humidity and work load. Low temperature, high humidity and work load were conditions which contributed to greatest efficiency. Brouha, et al (32), did find similar results. They reported metabolic efficiency as being approximately the same at normal and warm humid environs but increased in the warm dry conditions for both men and women.

Astrand (10) endeavoured to determine the mechanical efficiency at various work loads on the bicycle ergometer and to find out if there was any significant variation in their efficiency with age and sex. The subjects were comprised of females between 20 and 65 years of age and males ranging from 27 to 64 years of age. Her results showed that mechanical efficiency ranged from 18.9 at 300 kpm/min for the 50-68 year old males to 23.4 at 900 kpm/min for males ranging in ages 20 to 33, with the mean for all groups previously mentioned being 22.5 per cent. However, at 600 kpm/min no difference was found between relatively young housewives and physically well-trained students. In the male groups there was a significantly lower mechanical efficiency at 300 and 600 kpm/min for the oldest group when compared to the youngest group but not so at the 900 kpm/min level. She concluded that 50-60 year old draymen engaged by the breweries in Stockholm cycled with the same mechani-

cal efficiency as young students but that a decrease in mechanical efficiency during cycling did take place with increasing age.

Gary and Wishart (66) studied the existence of the most efficient speed in bicycle pedalling and the problem of determining human muscular efficiency. Results indicated that optimum gross efficiencies obtained were 16.3 per cent in one subject and 18 per cent in the other. These optima were obtained at about 52 pedal revolutions per minute, when the duration of contraction of the effector muscles could not have exceeded 0.6 second. They thought that it was impossible to obtain experimentally the real efficiency of effector muscles in any human effort, owing to the difficulty of getting an accurate no-load base line.

Astrand (16) studied mechanical efficiency during cycling in 21 male and 31 female subjects. Total energy was calculated from the values of oxygen intake during work with the basal metabolism calculated according to Mayo Foundation Standards and the caloric coefficient of oxygen was set at 4.90 calories per litre. Work intensities were performed at 900, 1200, and 1500 kgm/min for males and 600 and 900 kgm/min for females. In both cases pedal frequency was 50 rpm. For males the efficiency was fairly constant and varied between 23.3 and 23.7% while for females it was 22.5% at 600 kgm and 23.1% at 900 kgm. According to this study, for well-trained adult individuals the net efficiency, then, is about 23% independent of sex.

Astrand and cohorts (15) showed that of the eight obese women tested, at 300 kpm/min on the bicycle ergometer, the gross oxygen intake averaged 1.05 l/min giving a mechanical efficiency of 18.2 per cent. The average mechanical efficiency of 18.2 per cent was significantly lower than the

value of 21.0 obtained on the female subjects without evident obesity ($P<0.01$) and the difference in gross oxygen intake was highly significant ($P<0.001$).

The same trend was observed among the 4 men tested at the same work load. The oxygen intake was 1.08 l/min with a mechanical efficiency of 18.8 per cent as compared with values of 0.96 l/min and 20.1 per cent respectively for the 25 normal control subjects tested at 300 kpm/min.

From the results obtained it was concluded that the mechanical efficiency of obese persons was not as great as normal persons.

Taylor, et al (129), studied boys 7 to 15 years of age with regards to mechanical efficiency in cycling. They reported that with boys 7 to 9 years of age the average gross efficiency was 13 per cent while the average net efficiency with basal metabolism deducted was 18.4 per cent. With boys 9 to 11 years of age, the average gross efficiency was 15.7 per cent and the average net efficiency with basal metabolism deducted was 22.8 per cent, while for boys 12 to 15 the average gross efficiency was 12.9 per cent and the average net efficiency with basal metabolism deducted was 17.9 per cent.

Henry and Demoor (70) studied the metabolic efficiency of exercise in relation to work load at constant speed and found that the mean net efficiency at the heavier load, 19.3 per cent, was significantly less than the 21.2 per cent efficiency found with the lighter exercise. The authors postulated that the lower metabolic efficiency was due to the lactic debt mechanism while the alactic mechanism did not affect metabolic efficiency to the same degree. In this same study a number of other cases were cited where efficiency was increased, where some did

not change and others decreased as a result of an increase in work load. Therefore, we can recognize in part the reason for much inconsistency in results on mechanical efficiency.

Leblanc's (88) viewpoint differs slightly from that of Henry and Demoor (70). He (88) is of the opinion that the efficiency of a worker is not always dependent on the energy expended. This has shown to be the case when work is done in a warm environment or by subjects who are overdressed, as is often the case in the Arctic. The work output in these cases may be relatively low when fatigue is experienced, so that mechanical efficiency would also be low.

Dickinson (49) endeavoured to study the efficiency of bicycle pedalling as affected by speed and load. She found that the efficiency was low for both high and low rates of pedalling, and that it passed through a maximum value of 21.5 per cent for one foot movement of about 0.9 seconds. The effect of load on efficiency, with the speed of pedalling kept constant (33 revolutions per min.) at a value found to give the maximum efficiency in the previous series of experiments, was studied. Results indicated that within the range used, change of load had no appreciable effect on efficiency if the speed of pedalling remained constant.

Consistency in results is difficult to obtain because of various phenomena that affect mechanical efficiency on a bicycle ergometer. Factors such as age, sex, temperature, weight and training are variables which cause results to vary when determining mechanical efficiency. This can be seen in the literature presented herein where the mechanical efficiency on the ergometer varies from 17 to 24 per cent.

Effect of Exercise, Training, Age and Sex on the Respiration and Circulation in the Lungs

Because of exercise, a progressive and disproportionate increase in ventilation at increasing work loads occurs. This disproportionate increase in ventilation is usually referred to as hyperventilation of severe exercise. During severe exercise, when the amount of oxygen supplied by the circulatory system is insufficient to meet the needs of exercising muscles, the anaerobic metabolism is called upon to supply the deficit. Anaerobic metabolism causes an accumulation of acid metabolite in the blood and the lactic acid level rises. The extra lactic acid produced is buffered and extra carbon dioxide is blown off in the lungs. As a result either the pH must fall or the ventilation must increase or both. However when excess CO_2 is blown off in the lungs in response to the increased respiratory stimulus a fall in pH occurs. The expiratory exchange ratio rises as the pH and $PaCO_2$ fall and PaO_2 rises. McIlroy (94) contends that these changes account for the hyperventilation of severe exercise.

It is the opinion of some researchers (16, 103) that the respiratory system may play a large part in limiting MVO_2 while others (74, 15) believe the contrary.

Astrand (16) is of the opinion that during heavy work the ventilation gives a subjective feeling of strain that probably will be of great importance as a limiting factor in exercising to reach one's MVO_2. He also believes that a definite relief is felt when an oxygen rich mixture is breathed during severe work which increases the performance, and finally that the circulatory and respiratory systems will probably be

most decisive factors for determining the magnitude of the aerobic capacity.

After studying the effects of short muscular exercise on the bellows function of the lungs, Anderson (5) concluded that the vital capacity and maximum breathing rate of healthy adults, indicate that the limiting factor in exercise for the average adult person is unlikely to be the respiratory system.

Otis (103), in his article, believes also that during heavy exercise the oxygen demand for the respiratory work is probably great. Due to the large demand, pulmonary ventilation might be a limiting factor in the sense that further increases in ventilation will make no more oxygen available without lowering of PO_2 and the higher the ventilation the smaller is the total proportion of total O_2 that is available for the usual work.

Naimark, et al (100), studied 33 normal subjects and 10 cardio-pulmonary patients while continuously measuring the ventilatory exchange ratio during exercise. Results showed that when the work level at which the ventilatory gas exchange ratio (R) increases was appreciably above its resting level, it corresponded to the level at which arterial lactate increased and plasma bicarbonate fell. It was concluded that when O_2 supply is inadequate as in heavy exercise in normal subjects not only is there more anaerobic metabolism, greater accumulation of lactate, and greater oxygen debt but the ventilatory gas exchange ratio also increases during exercises of short duration (4-6 min.) depending upon the intensity of the exercise and the fitness of the subject.

After completing a review of the literature on circulatory changes

in the lungs during exercise, Shepherd (116) observed a number of adjustments by the body to exercise. It was noted that in non conditioned young men blood flow through the lungs increased 20 to 25 l/min while in trained athletes the increase was 25 to 30 l/min. Some authors have found a definite increase in pulmonary pressures and as the exercise load became heavier a greater increase in pressure has also been observed. The carbon monoxide diffusion capacity, the pulmonary capillary blood volume and the true diffusion capacity of the pulmonary membrane increased with the increase in pulmonary blood flow. It was also noted that the diffusion capacity of carbon monoxide increases during exercise owing to an increase in the effective pulmonary capillary membrane. The volume of the pulmonary capillary bed may increase by the opening of more capillaries or by distension of capillaries already patent. In normal subjects it was found that the clearance rate of carbon dioxide varied from about 20 per cent per second at the base of the lung to virtually nil at the apex. This difference is reduced with moderate exercise.

During exercise the normal pulmonary vessels can accommodate a three to four-fold increase in flow with about a 50 per cent increase in perfusion pressure. There is about a 10 per cent increase in the total volume of blood in the lungs which may be accounted for mainly by the increase in blood capillary volume. The diffusion capacity is increased, the concentration of red blood cells is increased, and a relatively uniform ventilation perfusion ratio is achieved through the lungs.

Newman and associates (101) compared 11 athletes and 9 nonathletes, closely matched in body size and age with regards to pulmonary alveolar-capillary diffusion. Pulmonary permeability (KCO), diffusing capacity

(DCO), oxygen consumption (VO_2) and pulse rate measures were taken first at rest and later during exercise. Findings illustrated that athletes had a higher mean resting pulmonary diffusion (KCO and DCO) but the difference was not statistically significant. Athletes also had a somewhat better oxygen extraction but the difference was not significant. When maximum work capacity was reached, the mean KCO, DCO, VO_2, Va (minute volume) and pulse rate were all significantly different for the two groups. When one subject, a non athlete, was put on a training schedule, with the exception of KCO, all measurements fell during training and rose after its cessation.

The above study shows clearly the effect training has on the movement of air in the lungs implying numerous advantages trained persons have over untrained. The explanation for the increase in KCO, DCO, and VO_2 is not clear, therefore present theories are speculative.

Anderson (5) studied the respiratory and circulatory fitness for muscular work in 140 adults ranging in ages 16-96. All work was performed on a bicycle ergometer at work loads of 500, 1000, and 1500 kgm/min with a constant pedalling rate of 67 rpm's. The subjects were composed of athletes, some champions, and sedentary individuals involving just daily activities. Subjects of 70 years of age or older were physically the best part of the elderly population, thus not giving results of normal subjects. Observed results showed an age difference for CO_2 recovery time, with the best recovery time being between 20 and 30 years of age. From the age of 30 the recovery time increased and in men was about doubled at the age of 70. Women were found to have a longer CO_2 recovery time than men although the difference was reduced in advanced

age groups. Athletes were found to have a shorter respiratory recovery time than non athletes. Physically active elderly men have on the average a shorter respiratory recovery time than sedentary elderly men.

When performing the same amount of work, extra ventilation increases with age. Women have on the average larger ventilation than men. Physically active men on the average have a lower extra ventilation than sedentary men. The differences of the mean values are statistically significant between subjects below 30 years and above 50 years at 1000 kgm load.

Anderson (5) concluded that vital capacity and maximal breathing capacity of healthy adults indicate that the bellows function of the lungs is unlikely to be a limiting factor in exercise for the average person.

Astrand (16) studied lung volumes and related them to age and sex determining the total, vital and residual capacity for 45 males 20-33 years of age and 51 females 20-25. The average values for females were 26 per cent lower than for males.

In this same study the maximal ventilation, respiratory rate and tidal air have been determined during running for 113 males (4-33 years) and 112 female subjects (4-25 years) with regards to age and sex. Results indicated that males attained higher average values than females for the maximal ventilation per minute except in the age group 12-13 years.

The maximal respiratory rates were similar for the two sexes up to adult age, while maximal tidal air before puberty was fairly equal. After 14 years of age the average values for males was higher than

females, 5 to 6%.

Cohen, et al (cited in 10), investigated 21 normal male subjects ranging in age from 17 to 76 years with regard to lung efficiency. They reported that maximal diffusing capacity of the lungs (DO_2) decreases with increasing age. According to their regression equation a 25 year old male has a DO_2 of about 59 ml/O2/min/mm mean oxygen gradient, and a 56 year old has a DO_2 of about 42. This shows a 29 per cent decrease. They feel that it is unlikely that there is any difference in this respect between the two sexes. The decrease in the capacity for O_2 uptake for the corresponding ages in this study was 17 per cent. When comparisons of the DO_2 and VO_2 were made, DO_2 decreases faster with age than MVO_2. The results of Cohen, et al (10), imply that one limiting factor for oxygen consumption in heavy exercise for older people might be the diffusing capacity of the lungs.

Maximal oxygen consumption can be affected by numerous factors in the circulatory and respiratory functioning of the lungs. Agreement on the specific changes in the lungs and the changes that occur as a result of exercising and training is not in the least unanimous. However, the review of literature illustrated that exercise and training had beneficial results in so far as respiration and circulation were concerned. As a result of these two parameters the efficiency of the lungs was increased. Observations of the writings herein showed that age and sex both affected the efficiency of the lung. Age, as in most other physiological parameters causes the efficiency of the lung to decrease once the individual passes the age of 30 years. The efficiency of the females' lungs, in terms of respiration, varied from 5 to 24 per cent below the values

obtained by the males in similar age groups. Once again, it was apparent that the sex of the individual had definite effects on respiration and circulation in the lungs.

Training as Related to MVO_2 and MHR

In spite of the voluminous literature on the effect of training on the body, some crystallization of opinions and ideas is coming about, but few specific conclusions can be drawn. However, the consensus of more recent evidence suggests progress in accumulating general knowledge about training.

Freedman, et al (64), studied the effects of training on response of cardiac output to muscular exercise in athletes. They reported that when a subject performed a standardized exercise in the untrained and trained state, a comparison of the total excess oxygen requirement showed no change. It was concluded, that no attributable differences to training were seen in the way a trained or untrained athlete meets the tissue demands. This was the case for an increased supply of oxygen during exercise, up to levels of 2 litres of oxygen intake per minute. They did note, however, that maximum breathing capacity increased.

Several other researchers (17, 34, 41, 62, 64, 74, 78, 128, 135) obtained more positive results from training. Fletcher (62), in his study, showed the differences between trained athletes, active athletes and non athletes in the length of time each could perform the test. He reported trained athletes performed longest with active athletes and non athletes following respectively. The effect of training was shown on the latter two categories when heart rate decreased for specific work loads and an

improvement as high as 500 per cent was obtained on the non athletes.

Astrand (17) made a comparison of elite athletes and normal individuals. He observed that elite athletes had a high capacity for oxygen intake per kilogram body weight, 67 ml or more opposed to the average of 58.6 ml/kg/min for a group of students of the same ages. In fact Astrand (17) made determinations on the Olympic skiing champion of 1956 and got 82 ml/kg/min or 5.88 l/min, the highest reading known, according to Dill (50).

Buskirk and Taylor (34) studied maximal oxygen intake and its relation to body composition, with special reference to chronic physical activity and obesity. They found that when comparisons of maximal oxygen intake of athletes to non athletes was made, athletes were superior in the possible level to be attained. Within the group of athletes reported, cross country runners were highest by far, with football and wrestling and intramural sports following and above the mean for non athletes. The mean maximal oxygen consumption of the cross country group was significant at the .01 level of confidence when compared to the three other groups.

Holmgren and associates (74) reported that prolonged intermittent training causes an increase in physical work capacity which also corresponds to an increase in blood volume. They further observed that physical work capacity increased after continuous short term training but not in the same proportion as intermittent long-term training.

Taylor (128) studied the effect of work load and training on exercise heart rate. After pedalling a bicycle for 45 minutes at a mean of 920 kgm per minute, heart rate decreased over the training period. Also heart rates in nearly all cases rose linearly with work load throughout

the low and intermediate ranges. Taylor, et al (132), in another study, obtained similar results. They studied two types of individuals, the athlete and the sedentary male, in the third decade of life. The observations showed that the well conditioned man had a lower pulse rate at rest and at all levels of work.

Wahlund (135) determined the physical working capacity of his subjects on a bicycle ergometer for a period of 6½ minutes. The subjects pedalled for this period at work loads of 600, 900, 1200 kgm/min or until exhausted, with no rest between work loads. From his observations, a comparison between ordinary healthy subjects, moderately trained subjects, and athletes was made in regards to MVO_2 and MHR at 600, 900, and 1200 kgm/min. The ordinary healthy subjects had 1.36, 1.87, and 2.39 l/min mean MVO_2 at 600, 900, and 1200 kgm/min while the athletes had 1.47, 1.94 and 2.40 l/min at the same work loads. Mean heart rates for the ordinary healthy subjects at 600, 900 and 1200 kgm/min were 115.3, 137.4 and 158.5 l/min respectively while for the same work loads moderately trained healthy subjects had 109.5, 125.5 and 142.5 l/min and athletes had 99.9, 117.4 and 136.4 l/min respectively. Without doubt it can be concluded for subjects in this study that training does affect MVO_2 and MHR.

Linde (91), in his article on an appraisal of exercise fitness tests, is of the opinion that a trained individual is in a better state of physical fitness. The state of a trained person is illustrated by the fact that the trained individual has less increase in heart rate for any given energy output, less rise in respiratory rate, and can perform more work before his blood lactate exceeds 65 mg per cent. The ability of the individual to achieve a higher MVO_2 and cardiac output are correlated with

a higher hemoglobin level, blood volume and heart rate volume (91).

Crescitelli and Taylor (41) reported a study in which the blood and urine lactate concentrations were determined during work of various types. They found at these specified work loads that as a group, less fit individuals appeared to have a significantly greater blood lactate concentration throughout the entire period of the lactate response to the exercise than did fit individuals. They also showed that the total excess urine lactate in response to the activity was significantly related to the fitness of the group.

Johnson and Brouha (78) showed that more physically fit persons can tolerate greater amounts of blood lactate than those who are not as physically fit. Their observations were (78):

1. For easy work that both can sustain in a steady state:

Measurement	Fit Man	Unfit Man
Oxygen Consumption	Lower	Higher
Pulse rate during work	Lower	Higher
Stroke volume during work	Larger	Smaller
Blood pressure during work	Lower	Higher
Blood lactate during work	Lower	Higher
Return of Blood Pressure to Normal after work	Faster	Slower
Return of pulse rate to resting value after work	Faster	Slower

11. For exhausting work that neither can sustain in a steady state:

Measurement	Fit Man	Unfit Man
Maximal oxygen consumption	Higher	Lower
Maximal pulse during work	Usually Lower	Usually Higher

Measurement	Fit Man	Unfit Man
Stroke volume	Larger	Smaller
Duration of work before exhaustion	Longer	Shorter
Return of blood pressure to normal after work	Faster	Slower
Return of pulse rate to resting value after work	Faster	Slower

When Johnson and Brouha (78) compared different groups on the treadmill test that they used, a definite difference was noted between those who were more fit or had a greater work capacity and the others who were unfit or had a lower work capacity. In order to distinguish between fit and unfit men a score below 40 was considered poor, 41 to 75 was considered average, 76 to 90 was considered good, above 90 was superior, and above 110 excellent, which very few men could attain.

Comparison among Different Groups of Men:

Subjects	Average Duration of Exercise Treadmill tests	Fitness Mean	Index Extremes
10 oarsmen in training	5 mins.	94	141 - 81
16 cross country runners varsity in training	5 mins.	94	125 - 81
13 freshmen cross country runners in training	5 mins.	87	100 - 77
10 college students in good condition, no regular training	5 mins.	78	92 - 67
10 college students in average condition, no regular training	3 mins. 32 sec.	52	58 - 42
10 college students, medically normal, in poor condition, no training	2 mins. 18 sec.	35	42 - 25
10 laboratory workers, no regular training	3 mins. 20 sec.	52	90 - 20

In most cases the literature herein attests to the fact that training actually does influence MVO_2 and MHR. It was shown that training did increase the MVO_2 capacity of individuals. This was clearly illustrated when comparisons between fit men and unfit men were drawn, illustrating a large difference in PWC between the two groups, with the difference in favour of the fit men. It was also observed that training decreased the heart rate for specific work loads therefore enabling the individual to carry on exhaustive work for a longer period of time, as well as allowing the individual to recover more quickly from both light and heavy work loads. Thus one can see that training did have a specific effect upon the above stated parameters.

Smoking and its Effects on the Body During Rest and Exercise

Many investigators have studied the effects of smoking with the results often being contradictory to previously found observations. Knowledge of its effects during rest is not quite as controversial as observations of smoking during exercise.

The effect of smoking 2 cigarettes for 12-16 minutes was studied on 6 normal subjects by Roth, *et al* (110). Observations indicated a drop in the cutaneous temperatures of the extremities of all subjects both in the supine position and when the subjects were normally clothed and sitting or walking. The basal metabolic rate and heart rate increased while the T wave amplitude decreased. Intravenous injections of saline and nicotine were carried out, with the former injection causing a slight drop in cutaneous temperature and the latter causing a pronounced and rapid decrease in cutaneous temperature. Both the smoking and nicotine

caused an increase in blood pressure and heart rate, as was also found by Autio, et al (23). Numerous authors (33, 89, 92, 93) have demonstrated that smoking produced vasoconstriction of the peripheral blood vessels of the extremities and elevation of the blood pressure and pulse rate in normal subjects. Several writers (25, 139, 140) observed significant vasoconstriction in the digits of normal subjects after smoking. In contrast, Mulinos and Shulman (119) determined the effect of smoking on peripheral circulation and cutaneous temperature of the fingers and concluded that the greater part of the observed decrease of blood flow could be accounted for by deep breathing. Smithwick (122) likewise reported a decrease of blood flow through a finger after a deep breath, immersion of the contralateral hand in cold water, a loud noise or even an unpleasant thought. Weathby (136) also noted that such stimuli may cause changes of cutaneous temperature comparable to those produced by smoking. However, he also found that vasoconstriction took place after smoking standard cigarettes but when nicotine was removed from them vasoconstriction was abolished, almost completely. It was also noted that when the subjects were ambulant, vasoconstriction of the peripheral blood vessels did not occur during smoking of standard cigarettes.

In contrast to most of the above findings, Evans and Stewart (94) found a similar decrease in peripheral blood flow with reduction of cutaneous temperature of the extremities as a result of smoking standard cigarettes, denicotinized or cigarettes not containing any nicotine.

Goddard and Voss (68) observed that pulse rate and respiration rates were usually higher and that body temperature was either higher or constant.

Johnson and Short (80) observed a rise in peripheral skin temperature after smoking, while Short and Johnson (118) noted that pulse rate, blood sugar, peripheral skin temperature and blood pressure were similarly influenced by smoking.

Heistand, et al (73), stated that changes in responses of their subjects over a period of 45 minutes, to smoking, were increases in heart rate, blood pressure, oxygen pulse and metabolic rate. Haggard and Greenberg (69) expounded that the respiratory quotient reached its peak in about 15 minutes after smoking and during the next 30 minutes returned to normal or slightly below. The work of Dill, Edwards and Forbes (53), on ten subjects, indicated that smoking of one cigarette resulted in no appreciable change in respiratory quotient.

Moutis (99) endeavoured to determine what residual differences in a number of certain cardiovascular measures exist between young men who smoke and others who do not smoke. Measurements of pulse rate, systolic blood pressure, diastolic blood pressure, pulse pressure, systolic amplitude and diastolic amplitude were made by means of the Cameron Heartometer. When comparison of smokers to non-smokers was made, numerous conclusions were drawn. The smoking group was found to have higher, though not significant, mean pulse rates, systolic blood pressures, pulse pressures, and systolic amplitudes in the sitting basal position. The smokers elicited larger changes in more of the six cardiovascular factors than did the non-smokers during the testing, with the largest mean difference measurement being found in the pulse rate. Here the smokers had a faster pulse rate. After completion of the study it was noted that the residual effects of smoking in young men could not be demonstrated signi-

ficantly in the selected cardiovascular factors.

Levy, et al (90), studied the changes in cardiac output as determined by the ballistocardiograph, changes in heart rate and blood pressure and wave alterations using the electrocardiogram. No significant differences in response either between those who smoked regular and denicotinized brands was found between normal and cardiac patients. The averages of the maximal changes observed in both groups showed slight increases in heart rate, systolic and diastolic pressures. In neither group was there a significant change in the average cardiac output. Changes in the electrocardiogram tracings occurred in less than half of the subjects in each group. These were slight and consisted mostly of diminished amplitude of the T waves. They concluded that, with the exception of susceptible persons, cigarette smoking caused slight changes in circulation and did not increase significantly the work of the heart.

Earp (56) conducted a study of athletes who took part in some of the sports events at Antinoch College in 1924-25. The study revealed that in one of the track meets held at the college, non-smokers had eight to twelve first places, light smokers received two, while medium and heavy smokers had each received one. However with equally startling results Dawson (48) found that 11 of the 28 men who finished in a Pittsburgh marathon used tobacco and four of the first five were moderate smokers.

In 1958, a survey of 285 athletes (4), was conducted at the British Empire Games to determine the number of smokers in the group. It revealed that 16 per cent of the athletes smoked to some degree, 7 per cent smoked fewer than 5 cigarettes a day, 5 per cent between 6 and 10

a day and slightly over 4 per cent more than 11 a day. This then indicates that approximately 1/3 of the athletes in this particular group smoked to varying degrees, indicating that some athletes feel smoking is not harmful.

Karpovich and Hale (82) studied the effect of tobacco smoking on physical performance. They studied 13 students, 8 of whom were habitual smokers and 5 non-smokers, by exercising them on a bicycle ergometer. Observations indicated that the average riding time for all but one subject was better when they did not smoke. Statistical significance showed for only two non-smokers and three smokers but was not significant for the group.

Shapiro and associates (115) endeavoured to study differences in tests of ventilatory function of 7 superbly conditioned non-smoking athletes, 5 non-athletic non-smokers and 7 non-athletic smokers. To detect the differences between the groups a Servo spirometer was used when measuring the airflow and volume changes. Results showed that vital capacity and maximum breathing capacity of the athletes were distinctly the largest, while the non-smokers and smokers were similar in this study. They also indicated that forced expiration peak flow and acceleration were comparable in the athletes and non-smoker non-athletes, both slightly higher than the smoker non-athletes. The athletes had greater vital capacity, higher air flow values during the first portion of inspiration, than non-athletes.

Reeves and Morehouse (105) studied the acute effect of smoking upon some of the physiological components of athletic performance in habitual smokers. More specifically, tests of speed, strength, ability and endurance were administered to all subjects under two conditions. Con-

dition (a) was a non-smoking period two hours prior to the test, (b) was inhaling 2.7 litres of smoke from one cigarette. The speed test of tapping was used to measure functional condition of the central nervous system and strength was measured by grip and push dynamometers. The Sargent Jump Test was used to measure muscular power, or to exert a large force in a short time, while the Harvard Step Test was employed to measure endurance and degree of displacement of physiological homeostasis.

Results from this study showed that smoking did not appear to have any influence upon the performance of any of the above tests. Further observation indicated that if a person were a habitual smoker, it made no difference in his physical performance whether he abstained from smoking for a few hours before performing or whether he smoked to the start of the event.

The study by Anderson and Brown (7) was done to determine the effects of cigarette smoking upon grip strength and recuperation from local muscular fatigue. It was observed that smoking one cigarette had no significant effect upon grip strength and recuperation from local fatigue of the flexors of the hand, within the time period used in this study. The experimenters noted the effect of familiarization throughout the second test as group mean grip scores were higher than in the first test. This would to some degree explain the results Willigoose (110) obtained when he studied the effect of tobacco smoking on strength and muscular endurance, and concluded smoking acted as a depressant in grip strength performances and decreased the ability to recover from fatigue. Kay and Karpovich (137) criticised this study on the basis of learning, in that the individuals learned how to use the dynamometer and therefore

were able to obtain higher scores on the second trial or series, which was the non-smoking series.

Kay and Karpovich (83) also studied the effect of cigarette smoking on repeatedly squeezing the hand dynamometer to secure information with regards to local muscular fatigue. No significant difference was obtained between a smoking and non-smoking group. Thus it was concluded that smoking of one cigarette by habitual smokers had no effect on recovery from fatigue of the flexors of the hand which agrees with Anderson and Brown (7).

Chevalier, et al (36), found, when comparing smokers with non-smokers, that for a specific exercise period of 5 minutes on the bicycle ergometer there was no difference in oxygen consumption measured during the exercise period. During the recovery period the oxygen consumption for the smokers was consistently greater than that of non-smokers and this difference was highly significant ($P<.001$). Both the resting and exercising heart rates were found to be significantly higher ($P<0.02$) in the smokers than in the non-smokers.

Henry and Fitzhenry (71) studied oxygen metabolism of moderate exercise with some observations on the effects of tobacco smoking. These results are in agreement with Chevalier, et al (36) that smoking had no statistically significant effect on exercise metabolism in any of the measured aspects.

Steinhaus and Grunderman (123) reviewed several experiments concerned with the problem of the effects of tobacco usage and almost without exception these studies revealed harmful effects.

Upon review of the literature, it is possible to generalize that

during rest smoking lowered the body temperature of the extremities, it increased the pulse rate, systolic blood pressures and other selected physiologic parameters. On the other hand the evidence of the effects of smoking upon the body during exercise is not as lucid as the above findings during rest. However, the evidence gathered did show that the non-smokers did perform at least as well as the smokers and in other cases were better. From that statement one could say that smoking did not improve performance as none of the smokers performed better than the non-smokers.

Test Comparisons of Various Types

Kraus - Weber and AAHPER Test Comparisons

Comparison in motor performance between North American and European children (35, 84, 87, 138), has implied that North American youth are unfit. Yet, according to life expectancy (138), Canadian and American youth are more fit than ever before. Comparisons of cardiovascular tests by Adams, et al (2, 8) and Rodahl, et al, (108, 109) failed to show significant differences between European and American children.

The Kraus - Weber test (87), more than any other, was responsible for making the North American public cognizant of the physical work capacity of modern day youth. Kraus and Hirschland tested 4,264 United States children and 2,879 European children on a simple six-item test and found that 57.9% of the United States youngsters failed one or more of the test items compared to 8.7% of the European youngsters. Kraus also said (87:185):

> These tests represented minimum fitness tests; that is, they were tests which indicated a level of strength and flexibility

> in certain key muscular groups below which functioning of the whole body as a healthy organism seems to be endangered. Furthermore, patients whose physical fitness level fell below these minimum requirements appeared to be "sick people," individuals who have all the earmarks of "constant strain," and who frequently manifested signs of emotional instability.

There has been much controversy about the Kraus - Weber test, mainly as to whether or not it is a test of fitness. Some writers (75, 76) have produced evidence which shows that with very little practice the failure rate is not so alarming, and that children who fail the test do not differ in personality from those who passed, as inferred by Kraus. The test itself may be criticised in that it employed movements that are quite similar to those found in the gymnastically-oriented European physical education and sports programs, and therefore, the possibilities of success would be in favour of the Europeans, causing fewer to fail and not really being a true comparison drawn between the two sets of children.

Schaffer (112) sought to analyze the relationship of certain variables upon the high rate of failure of Kraus - Weber Test for Minimum Muscular Fitness as applied to Junior High School girls and to determine the value of conditioning exercises. The study revealed that Kraus - Weber test failure is positively correlated with intelligence, and that intelligence, age, and physical type are interrelated with one another and with Kraus - Weber failure. Findings also showed that a program of exercises based on physiological needs produces rapid gains in strength and flexibility. In fact, after one semester of a program including conditioning exercises, the girls, most of whom had had no physical education before this experiment, equalled the European child's rate of success in passing the Kraus - Weber Test. The author noted that games were not sufficient enough to increase fitness and therefore lower the failure

rate, but that after two semesters of conditioning exercises the American girls performed 5% better than the European girls.

Rodahl, et al (108), studied children in Philadelphia and compared their results to those of Astrand (16). They found the Kraus - Weber Test for minimum muscular fitness showed no significant difference between the Philadelphia children and those examined in Stockholm or any of the other Swedish cities, (108).

The Kraus - Weber Test administered in East Pakistan in 1958 by Kelliher (84) showed that the fitness of Pakistan girls and boys was below European standard, but better than that of American children according to the data in the original Kraus - Weber study.

Daulrich (47) reported a study by Hale and Mathews which indicated that of a total of 1,334 elementary school boys tested with the Kraus - Weber tests, more than one-half of the boys failed. Forty-eight per cent failed the flexibility test and 14% failed the sit-ups with legs flexed. Less that 3% failed any of the other four items in the battery.

Fowler and Gardner (63) studied 77 subjects (46 cardiac, 14 muscular dystrophy and 17 asthmatic children) ranging in ages from 7-17 years with regards to the Kraus - Weber Test for minimum muscular fitness, and also determined the PWC of the children according to Sjöstrand (120). The same subjects were also given the AAHPER test, excluding the softball throw.

Results of the Kraus - Weber Test showed the greatest amount of failures to be in the abdominal strength and floor touch items. Children with muscular dystrophy, as would be expected, had the highest percentage of failures. When the Kraus - Weber was compared to other measurements

taken on these same children there was little relationship. Children with early muscular dystrophy had marked decreases from their predicted scores in both physical working capacity and motor performance tests. Subjects with congenital heart disease and asthma showed moderate changes from their expected scores in physical working capacity, but significant decreases in most tests of motor performance. Physical working capacity correlated moderately well with sit-ups, shuttle run, and the broadjump in boys and for girls, the shuttle run, 50 yard dash and the 600 yard run had a low significant correlation.

In 1958, the United States professional body, the American Association for Health, Physical Education and Recreation, published its own Youth Fitness Test. From a sample consisting of 8,500 boys and girls in grades 5 through 12, norms were set up. Since publication, additional information on test comparisons between countries and groups within countries has been available.

The AAHPER Youth Fitness Test was administered to over 10,000 British boys and girls in 1958-59 (35). It was concluded that the British boys were far superior to the United States boys in all the fitness tests except the softball throw for distance. The British girls were also superior to the United States girls. In fact, at certain ages, the British girls were superior in performance to United States boys, at ages 10, 11, 12 and 13 on the mean scores in five of the seven tests. It was also concluded that, in general, the British boys and girls and United States boys improved with age while the United States girls showed either little improvement or regressed with age. From this study the author stated that the unfit condition of the United States youth was

serious.

The same test was given to 319 males and 134 females, Danish school children, and again the results were compared to the United States norms (85). It was found that approximately 70% of the boys' scores and 86% of the scores of the girls exceeded the United States mean scores.

Wolffe (138) noted that physical fitness in Japan far exceeded that in America according to the AAHPER fitness test. In testing 20,000 Japanese youths it was found that they surpassed the Americans by wide margins in tests of arm strength for boys and girls. At various ages, Japanese girls showed 18 to 47% more arm strength than Americans. In tests of speed and agility, the Japanese children far out-performed the Americans, only at the 17 year old level did American performance in leg power tests equal the Japanese. The Oriental girls not only excelled in tests of sheer power, but far surpassed the American girls by larger margins than did the Japanese boys over U.S. boys.

Ikeda (77) compared the physical fitness of children in Iowa, U.S.A. and Tokyo, Japan, using the Iowa Test of motor fitness, which was administered to 395 Tokyo children and 355 Iowa children, 9 to 12 years of age. The test battery included: sit-ups for boys, bent arm hang for girls, standing broad jump, shuttle run, forward bend, grasshopper, pull-ups for boys, and 50 yard dash. It was concluded in the face of this experiment that there was a significant difference at or beyond the 5% level between the two samples in motor performances in favour of the Japanese children. More specifically with the exception of the sit-ups and the grasshopper, Japanese groups exceeded Iowa boys and girls. The Iowa groups exceeded the Japanese groups in sit-ups, and there was no signifi-

cant difference between Iowa girls and Japanese girls in the grasshopper.

A review of this literature showed that the test comparisons between United States children and those of other countries show differences in the level of physical fitness. This difference found was in favour of the other countries in the majority of cases except when a training program was set up for the U.S. children. Under the training conditions, U.S. youth approach, equalled or surpassed the score obtained in the other countries. However, it must be noted that unless the United States youth is given specific training, he does not approach most of the scores that youth from the other countries obtained.

Achievement Tests

Cratty (40) compared the scores achieved by fathers (1925) and sons (1959) in the following physical ability tests; broad jump, fence-vault, and 100 yard run. He tested the subjects at Pomona College by comparing the percentage of tests failed by each, determining the difference in the mean scores, and computing correlations between father and son performance in the tests. The findings indicated that a larger percentage of the tests was passed by the fathers and that their scores were significantly higher in 3 out of 4 of the tests. The highest positive correlations were noted between father and son performance in the broad jump (+ .86) and in the 100 yard run (+ .59).

Espenschade (59) reported a study on gross motor tests which were given to subjects of the California Adolescent Study in 1934 - 35. These same tests were given in 1958 - 59 to pupils of the same age and grade enrolled in the same school. Performance of boys and girls of today was

superior in jump and reach and in the dynamometer strength "pull" test. Boys of today excelled also on throw for distance, brace test, and grip strength. Boys and girls of 24 years ago were superior in the dash and broad jump.

Esslinger (60) reported that Physical Education in the U.S.S.R. receives strong support from the government because it is capable of achieving outcomes which are in the national interest. The opportunities are not restricted to school children but apply to both sexes of all ages. The aims of physical education in the U.S.S.R. are four fold: fitness, motor skills, moral qualities and Soviet patriotism. In the U.S.S.R. fitness is not only the development and maintenance of a high level of health and physical fitness but everyone is exhorted to exercise daily to develop maximum strength, endurance, sturdiness and agility. Motor skill development is of a wide variety and has utilitarian and military value to the Russian people. Emphasis is given to improving skill in walking, running, jumping, vaulting, climbing, balancing and in lifting and carrying heavy objects. Above and beyond the allotment of time for physical education periods the U.S.S.R. children have a daily 15 to 20 minute period of setting up exercises before classes. Until recently, U.S. schools did not give this type of exercise period to any of the pupils, however, some states have started.

The literature in this area was by no means unanimous in its point of view. Observations indicated that in some cases scores achieved by fathers were better than those achieved by sons as well as the converse being true in other specific test items compared. A question that may be posed here is, are comparisons of this type really possible in view of

all the variables involved?

Comparison of Physical Work Capacity

Rodahl, et al (108), selected 111 subjects from Temple University by use of the table of random numbers for his study. The subjects ranged in age from 18-22 years old. His subjects were compared to German soldiers and a Swedish adult population of the same age group. Results were also reported for children ranging in age of 7½ to 16½ years old. The test items for all the groups were:

1. measuring maximal oxygen consumption,
2. a modified step test,
3. pulse response at fixed work loads,
4. Leistungs - Pulsindex,
5. muscle strength,
6. manual dexterity, and the
7. Kraus - Weber Test for minimum muscular fitness.

Results obtained from the study done by Rodahl, et al (108), with regards to the above tests, indicated that when they compared maximal oxygen uptake they found that the Stockholm data reported by Astrand in 1952 (16) showed by far the highest values, with those of Robinson's studies in Boston (107) in 1938 next. The Philadelphia values were found to be comparable to the German values reported by Reindall, et al (106) in 1959, but were markedly lower than the Stockholm data. When Philadelphia female subjects, 20 to 22 years of age, were compared with Swedish housewives, 20-29 years of age, a marked difference in oxygen consumption was found in favour of Swedish females 2.123 liters per minute as

against 1.25 liters per minute in the Philadelphia subjects.

Upon analysis of the results of the Philadelphia subjects, they showed a statistical correlation between the maximal oxygen uptake, the muscle strength, the pulse response to fixed work loads (300, 450 and 600 kpm/min), and the performance in the Step Tests in the Philadelphia samples used.

When comparisons between the United States, German and Swedish children were made in the aforenamed variables, it was reported that:

1. there was no statistically significant difference in oxygen uptake at 600 kpm/min between Stockholm and Philadelphia boys 14 years of age,

2. a comparison of pulse response to fixed ergometer work loads of 300 and 600 kpm showed no statistically significant differences between the boys, but Swedish girls were significantly superior at both of the work loads listed,

3. the strength of the biceps (mean of right and left) for the Philadelphia subjects when compared with the Dortmund subjects of comparable age, showed no consistent significant difference between the two groups,

4. the manual dexterity as by O'Connor Test showed no significant differences between the Philadelphia and Dortmund subjects, and,

5. for the Kraus - Weber test, no appreciable difference was found between the Philadelphia subjects and the Swedish subjects, 14 years of age.

Adams, et al (1) studied the PWC of normal school children in the city and country in Sweden. They compared the slopes of the working-

surface area regression lines of Swedish city girls and of California girls and reported no significant difference. When comparisons of slopes of working capacity-surface area regression lines for Swedish country girls and California girls were made, it revealed a difference at the 1% level in favour of the Swedes. The same comparison was drawn for Swedish city boys and California boys, revealing a significant difference at the 1% level once in favour of the Swedish population. The authors believe the difference to be due to the narrow range of surface area in the Swedish boys studied. Regression line slopes showed no difference when comparing Swedish country boys with California boys.

Cumming and Cumming (44) studied the PWC of normal Winnipeg, Manitoba, Canadian children on a bicycle ergometer and compared them to a similar sample from California and Sweden. They also observed both medical students and nurses for the same comparative purpose. Two groups of subjects were selected. One group of 125 from 10 city schools in Winnipeg ranging in ages 6 to 16 were selected by the teacher according to ability in physical education. The 125 subjects were divided into 5 groups: 3 of average physical education ability, 1 better than average and 1 poorer than average. The second group of subjects was composed of 88 grade 6 students aged 11 and 12 and were broken down into four classes A,B,C,D. The first three (A,B,C) were from schools with two 30 minute periods of physical education per week. Group A was a group of students selected for outstanding scholastic ability and learning capacity. Class D (boys only) was selected from a private school where sport facitilities were superior and where students were required to take 2 P.E. periods weekly, plus 2 of competitive games.

Each subject was required to pedal 60 to 70 revolutions per minute for a 6 minute period, and after this period the work load would be increased until a PWC with a heart rate of 170 was reached. The 170 PWC was considered maximal. Findings showed that the maximal PWC for the male academic class was 8% lower, but not significantly, than for the average classes. The maximal PWC in private schools was higher (13%) but not significantly higher than that of the average classes. Of two groups tested in the same school, the average of class B was significantly higher (16%) than the academic class A in maximal PWC. A comparison of the two average classes shows maximal PWC to be similar.

When comparing the maximal PWC of Winnipeg boys to those from California it was found that California boys were higher with the exception of 8 and 13 year olds. With the exception of the 11 and 14 year old girls the maximal PWC's of California girls in kg/M/min/M^2 body surface area was greater than those of the Winnipeg girls. None of the differences are large.

A further comparison was made using 11 and 12 year old children who were not selected. Comparisons were expressed as per M^2 body surface to eliminate differences in body size. Maximal PWC's of California and Swedish children were similar, whereas, maximal PWC's of Winnipeg girls and boys was 14 and 19 per cent lower than Californian scores for both boys and girls respectively. The greatest difference was found when comparing the PWC of Swedish nurses to Canadian nurses, finding a 42 per cent difference in favour of Sweden.

Kramer and Lurie (86) compared the results of an Indianapolis study with previous reports in the literature. They found that untrained normal

boys had mean VO_2 values comparable to those reported by Robinson (107) in a 1938 Boston Study and Morse, et al (cited in 86) in 1948 in Chicago, higher than Reindall, et al (106) in a 1959 Freidburg, Germany study and Rodahl, et al (108) in a 1961 Philadelphia study and lower than Astrand (16) in a 1952 Stockholm Sweden study. Kramer and Lurie (86) further analyzed the trained male subjects in the 1962 Indianapolis group and found them to have higher MVO_2 values than reported by Astrand. It was also found that the trained normal girls from the Indianapolis sample had slightly higher MVO_2 values than Astrand's (16) and markedly higher than Rodahl's group of average normal girls.

The mean MHR was 191 in the average normal boys (age 9-16) and 192 for the trained normal boys (age 12-17). Comparable values in normal boys previously reported as cited in (86) are 190 by Boas in 1931 for boys (age 9-15 years), 196 by Dill and Brouha 1937 for boys (age 12-19 years), 195 by Robinson (107), in 1938 for boys (age 6-19 years), 196 by Morse, et al (86), in 1948 for boys (age 9½-17½ years), and 205 by Astrand (16) in 1952 for boys (age 10-18 years). In the case of Kramer and Lurie (86) the subjects were not run to exhaustion as they were in all other studies, except Boas, therefore not giving a true indication of the highest heart rates.

After surveying the writings presented, one finds that the results obtained in Sweden were higher than the results obtained in either California, Indianapolis or Manitoba. As a result, it seems reasonable to suggest that the Swedish population tested, was superior to the North American samples in both MVO_2 and MHR. However, in the study carried out in Indianapolis, the MVO_2 results obtained in the trained individuals were

higher than those obtained in the Swedish group. In the Manitoba study, PWC comparisons were drawn between groups who differed in intelligence levels, and between groups who were required to take a different number of physical education periods during the week. Observations showed that normal children who had the same number of physical education periods per week as the highly intelligent children, performed as well as the highly intelligent group. This same study also showed, as is normally expected, that the students who were engaged in more periods of physical education per week performed better than those with fewer physical education periods per week. Assuming the above statement to be logical and true, one can then infer that the Swedish groups generally have a better PWC because they exercise more.

Inter-racial Comparisons of MVO_2

Andersen and Hart (8) compared the aerobic PWC of the Eskimos, Arctic Indians and Caucasians. It was found that of the three groups Eskimos were in the poorest condition. It seems quite probable that another type of exercise to which the Eskimos are more accustomed may stimulate circulatory response of maximal effort to the same degree as that reported for Caucasians.

Andersen, et al (6) studied physical fitness of Arctic Indians and compared them to an average sample of Norwegians. Results indicate that oxygen cost of the Indians was only slightly higher than the average sample of Norwegian men who were accustomed to this type of exercise. The linear relationship between oxygen consumption and heart rate was also obtained in these results. The fitness of the Arctic Indians for

muscular work averages better than the fitness of men of sedentary habits in the Norwegian society.

The literature on this aspect is sparse, therefore generalizations of any sort are difficult to draw. However, from the articles reviewed three groups of individuals were compared, Eskimos, Arctic Indians and Caucasians. Observations showed that when the above three groups were compared Eskimos were in poorest condition. Results from another study, on a comparison of sedentary Caucasians and Arctic Indians, showed that the Arctic Indians were superior to the Caucasians in PWC. Despite the above observations, one must be extremely cautious when drawing conclusions about comparative type studies.

The literature reviewed pertained only to those aspects considered relevant to the problem. It was observed that MVO_2 was the best test to use when testing the PWC of an individual. It was also stipulated that if MVO_2 was to be used effectively as a measure of PWC, then large muscle groups had to be utilized. The review showed that the validity and reliability of both the MVO_2 and MHR were very good. In order to gain the best results and understanding of the MVO_2 test, the author felt that other factors which influenced MVO_2 and MHR should also be considered. The literature illustrated obvious effects of age upon both MVO_2's, and MHR's; the highest scores in both parameters were obtained in the 20 to 30 year age range and thereafter showed a steady decline. The effects of sex on MVO_2 and MHR were also definite. Men had higher MVO_2's than women but MHR's were similar. Hot environments were found to affect MHR's more than MVO_2's. Warm environments increased the work of the heart considerably, thus making it much more difficult to complete

a specific work task. Mechanical efficiency on the bicycle ergometer ranged from 17 to 24 per cent with the former score being that of individuals in the early teenage years and the latter score being for individuals in their late teens or older.

The literature showed that exercise and training improved both the respiration and circulation of the lungs, as well as many other physiological functions connected with them. Age and sex were also found to effect these same parameters. In each case the effect of age resulted in a decrease in respiratory and circulatory efficiency. Sex differences were once again obvious because female scores were below those of male scores. The effect of training on both MVO_2 and MHR illustrated that generally it was beneficial to train when performing difficult work and as a result both MVO_2 and MHR improved. A review of the literature with regards to smoking showed that smoking definitely affects the body during rest. However, the effects of smoking on the body during exercise were somewhat more difficult to illustrate. The results showed that in some cases smoking did affect physical performance whereas in other cases it did not affect performance.

Kraus - Weber test comparisons between American children and those of other countries illustrated that in all cases children from the other countries passed more of the test items than American children did. It was also observed, however, that with training, the results of American children were better than those from other countries. When AAHPER test comparisons were carried out by using the norms for U.S. children and comparing them to the scores obtained in other countries, once again, it was observed that U.S. children had inferior scores to those from the

other countries.

In the achievement tests performed, the differences between father and son were noted with better performances in more test items being accomplished by the fathers than by the sons.

When PWC comparisons were made between various countries, it was observed that the 1952 group from Sweden had the best scores. Other studies carried out in U.S.A. and in Germany had lower results but similar scores.

With regards to inter-racial comparisons of MVO_2's, and generalizations about them; little can be said because of the scarcity of the literature in this area.

However, despite the present findings, comparative studies must be accepted with caution. Before any comparisons can be made, numerous situations warrant close scrutiny, such as; the actual testing conditions of each of the groups, the type of test used, similarity in methods and procedures and innumerable other items. In fact it is very difficult to produce a standard test which does not favour any one country or group of individuals, because of the countless differences in geographic, socio-economic and cultural conditions.

CHAPTER III

METHODS AND PROCEDURE

Prior to the actual testing period, a pilot study was conducted. This enabled the experimenter to become familiar with the intrinsic problems, and the methods and procedures of testing.

The subjects used in the problem were selected by use of the table of random numbers, from students attending the University of Alberta. One hundred subjects, ranging in age from 18 to 22 years, were used for testing in both the problem and its subsidiary branches.

The testing was conducted over a period of five weeks, with a seven day period between the test-retest. In the retest, the original conditions were duplicated as closely as possible, including time of day and laboratory conditions.

The test was explained to each subject in the same manner. All the equipment used in the study was identified and its functions explained.

As is noted elsewhere (32, 37, 38, 39, 52, 81, 88, 111, 126, 132) temperature variations influence the efficiency of an individual to perform work. In the case of this study the laboratory temperature was standardized at $72 \pm 4^{\circ}$F.

In all cases subjects were advised not to eat or perform vigorous exercises for a 1½-hour period before the exercise and at the same time were asked to refrain from smoking for a ½-hour period previous to the exercise.

When the subject arrived at the specified time, his age, height and weight were noted as well as whether he was a smoker or non-smoker.

Test Apparatus

The following apparatus was used:

1. A Swedish Bicycle Ergometer Monark GCI (19, 134, 108) (Figure 1)
2. A Viso-Electrocardiogram - Sanborn 100 (Figure 2)
3. A Volumeter American Model 5-B-150 (Figure 3)
4. A Dayton Vacuum Pump Model 2-M-138 (for Volumeter) (Figure 3)
5. A Stop Watch Calibrated to 1/10th of a second
6. A Beckman E-2 Oxygen Analyzer (Figure 3)
7. A N.V. Godart K.K. Type Carbon Dioxide Analyzer (Figure 3)
8. Douglas Bags - size 150 to 200 liters (Figure 2)
9. A Franz Electric Mentronome Model LM-FB-3
10. A Modified Otis McKerrow Valve (Figure 4)
11. An adjustable lightweight headgear (Figure 4)
12. A Vacuum Pump for Oxygen Analyzer Model 18-309X (Figure 3) Serial Number 12V36449
13. Ten feet of corrugated plastic hose (Figure 2)
14. A Nasal Clamp (Figure 2)
15. A 9-foot stand with adjustable cross bar 4 feet long (Figure 2)

Test Method and Procedure

In attempting to assess physical work capacity, two tests were conducted: a maximal oxygen consumption test and a test of pulse response at fixed work loads.

Maximal Oxygen Consumption

Physical work capacity was assessed by the maximal oxygen consumption test as determined by measuring oxygen uptake at increasing work loads

FIGURE 1

MONARK GCI BICYCLE ERGOMETER

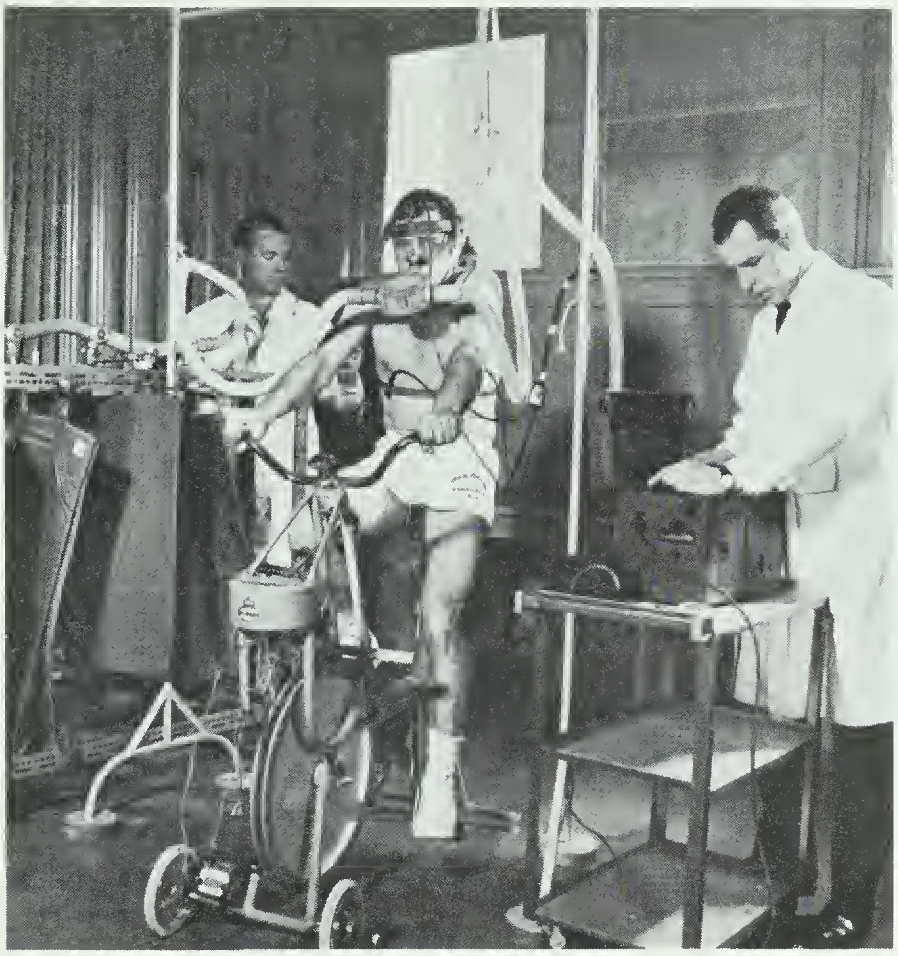

FIGURE 2

LEFT TO RIGHT DOUGLAS BAGS, ADJUSTABLE STAND, FLEXIBLE PLASTIC HOSE, PLACEMENT OF HEAD GEAR AND MOUTHPIECE, ELECTRODE ATTACHMENT, A NASAL CLAMP, RIDING POSITION, AND A SANBORN 100 VISO-ELECTROCARDIAGRAM

FIGURE 3

N. V. GODART CO_2 ANALYZER, VOLUME METER,
A DAYTON VACUUM PUMP FOR THE VOLUME METER,
A BECKMAN E - 2 O_2 ANALYZER,
A VACUUM PUMP FOR THE O_2 ANALYZER

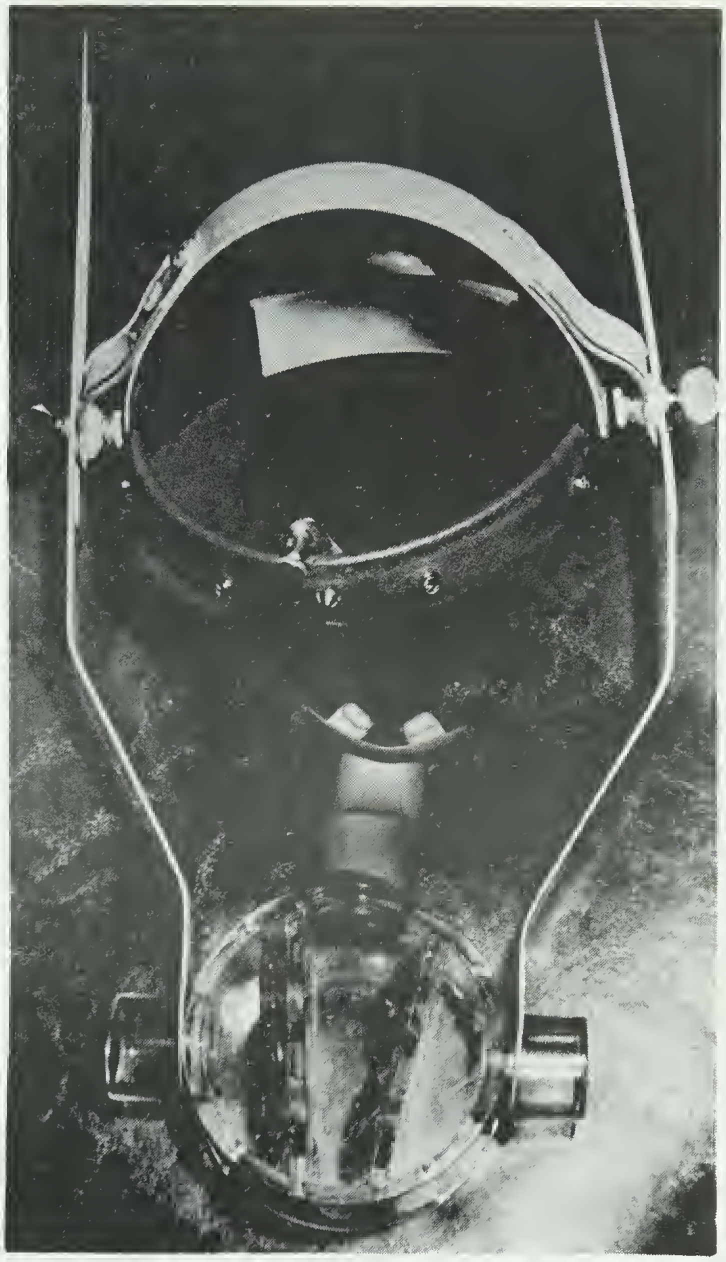

FIGURE 4

TOP ADJUSTABLE LIGHTWEIGHT HEADGEAR
BOTTOM A MODIFIED OTIS MCKERROW VALUE

on the bicycle ergometer until exhaustion of the subject took place. Exhaustion in all cases was that point at which the subject could no longer pedal the ergometer at a steady 50 cycles per minute, and complete the specific work load of the ride (being six minutes in length).

Procedure

Adjustment For Subject

The subject took the riding position on the ergometer, then the experimenter adjusted the seat so that the anterior portion of the knee cap was directly over the toe when the pedal was at the lowest point of its circular movement (figure 2). This, then, caused the subject to pedal with the tarsal metatarsal articulations of the foot. The subject was instructed to pedal in this manner at all times throughout the entire test.

Adjustment of the handle bar was individualized to suit the test subject, but once set for the subject it was not re-adjusted.

Preparation of Subject

The subject then had the adjustable headgear with the Otis-McKerrow valve with the mouth piece and electrode placed on his head (figure 4). This was also adjusted to the needs of the individual. The mouth piece, with the one-way valve, was adjusted to enable a smooth and easy insertion of the mouth piece when necessary. The individual was also prepared for recording heart rates during the different work levels. The recordings were processed by using a Sanborn portable electrocardiogram with the leads being attached to two electrodes, and a reference electrode which was located on the headgear on the forehead (see figure 2). Speci-

fic attention was directed to grounding the electrocardiogram and to preparation of the electrodes with Redux to ensure better recordings.

Performance of the Test

The subject was given a "count down" and on "zero" commenced to pedal the bicycle. A metronome, with a visual stimulus, was set at one hundred beats per minute so as to enable the subject to pedal at a cycling frequency of fifty cycles per minute for a period of six minutes. The resistance was zero when the test was started, but was quickly adjusted to the desired specific work load level. The adjustment was made by stretching the belt with the aid of one of the handwheels, causing resistance on the wheel, thus raising the marker on the scale to the desired reading. When the belt and wheel got warmed up as a result of the friction, the reading on the scale would change, therefore necessitating readjustment by means of the hand wheels. The load was checked at least once a minute to ensure its consistency at all times. At four minutes and thirty seconds, the mouth piece on the Otis-McKerrow valve was put into the subject's mouth and a nasal clamp placed on the subject's nose. At exactly five minutes a valve leading to a Douglas bag was opened and gas was collected for one minute while the subject performed during his final minute of work. At exactly the sixth minute of work, the valve leading to the gas bag was closed and the subject was told to stop pedalling. All subjects remained seated and rested for five minutes after which time they once again started to pedal for another work period. The first work load was 1 kp or 300 kpm, the second was 2 kp or 600 kpm, the third, 3 kp or 900 kpm and so on, until the subject was exhausted and could not continue to pedal to the beat of the metronome or for the required six

minute work period. If the subject did not complete the six minute work period, he would signal the experimenter to put the mouth piece in his mouth and place the nose clamps on and a gas sample would then be taken for one minute, if possible, or for either 45, 30 or 15 seconds of a minute. To ensure the investigators that the subject had reached his maximal oxygen intake, he would be given a five minute rest period, then would pedal at a work load one level higher than the last for as long as he was capable, with the same procedure followed as stated above.

Determination of Oxygen Consumption

Each day before the gas analyzing equipment was used, it was calibrated. The expired air in the Douglas bag was analyzed for percentage oxygen and carbon dioxide by drawing a sample of the expired air through the exit tube in the bag by a ½" vinyl hose into the Beckman E-2 oxygen analyzer and KK Godart Capnograph infra-red carbon dioxide analyzer. Expired air volume was determined by using a Collins P-553, 1/15 horse power centrifugal pump to draw the air out of the bag through a three-way Thomas valve, a 1.5 inch rubber hose and an 802 American Gasometer at a constant rate of 70 liters per minute (figure 3).

Pulmonary ventilation was expressed as liters of air expired per minute, the volume of gas being reduced to the standard temperature and pressure 0°C and 760 mm Hg, dry. The formula used was

$$\frac{P_B - P_{H_2O}}{760\ (1 + 0.0036\ T)}$$

where P_B = ambient barometric pressure.

P_{H_2O} = the vapour tension of water, mm Hg. at the temperature of the gas meter.

T = the temperature of the gasometer.

For calculation of oxygen consumption, the change in nitrogen content for correction of expired to inspired volumes, described by Peters and Van Slyke (104) was employed. The following was the method of calculation used:

1. The symbols shown were used for this study.

   a) Fe = % of a particular gas in expired air.

   b) Fi = % of a particular gas in inspired air.

   c) Ve = Volume expired.

   d) Vi = Volume inspired.

   e) ATPS = Atmospheric temperature, pressure, saturated.

   f) STPD = Standard temperature, pressure, dry.

2. The corrected percent of oxygen in the expired air is

   Ve air STPD = Ve ATPS X the factor for reducing a volume of moist gas to a volume of dry gas at 0°C and 760 m.m. of mercury.

3. The corrected percent of oxygen in the expired air is

   $$\text{Fe } O_2 = \text{Analyzer reading X } \frac{2.5}{1000}$$

4. The volume of inspired air is

   $$\text{Vi air STPD} = \text{Ve air STPD X } \frac{\text{FeN}_2}{\text{FiN}_2} \quad (\text{FiN}_2 = 79.03)$$

5. The total amount of oxygen inspired, but not all consumed, is

$$ViO_2 = Vi\ air \times \frac{FiO_2}{100} \quad (FiO_2 = 20.94)$$

6. The volume of oxygen expired, but not consumed, is

$$VeO_2 = \frac{FeO_2}{100} \times Ve\ air$$

7. The amount of oxygen consumed is

$$VO_2 = ViO_2 - VeO_2$$

Determination of Pulse Response at Fixed Work Loads

This measurement was accomplished by using a Viso-Electrocardiogram-Sanborn 100. Heart rate recordings were taken for the last 5 seconds of every minute. This test was done in conjunction with the maximal oxygen consumption test on the bicycle ergometer, allowing, therefore, the necessary data to be collected in one trial with the subject.

Preparation of the subject was described previously in this study.

Calibration of Bicycle Ergometer

The sinus balance was calibrated by means of a set of stainless steel weights, #750 Class S-1 Serial No. 7Y1458 (see figure 5) in the following manner (19:3).

1. The brake drum was removed and the mark on the pendulum weight was set at "0".
2. A one kilogram weight was attached to the spring as shown in Figure 5. Weights were added or taken from the spring as required to bring the mark on the pendulum to the required scale mark of "1-kp".
3. This technique was continued on through "2-kp", "3-kp", etc.,

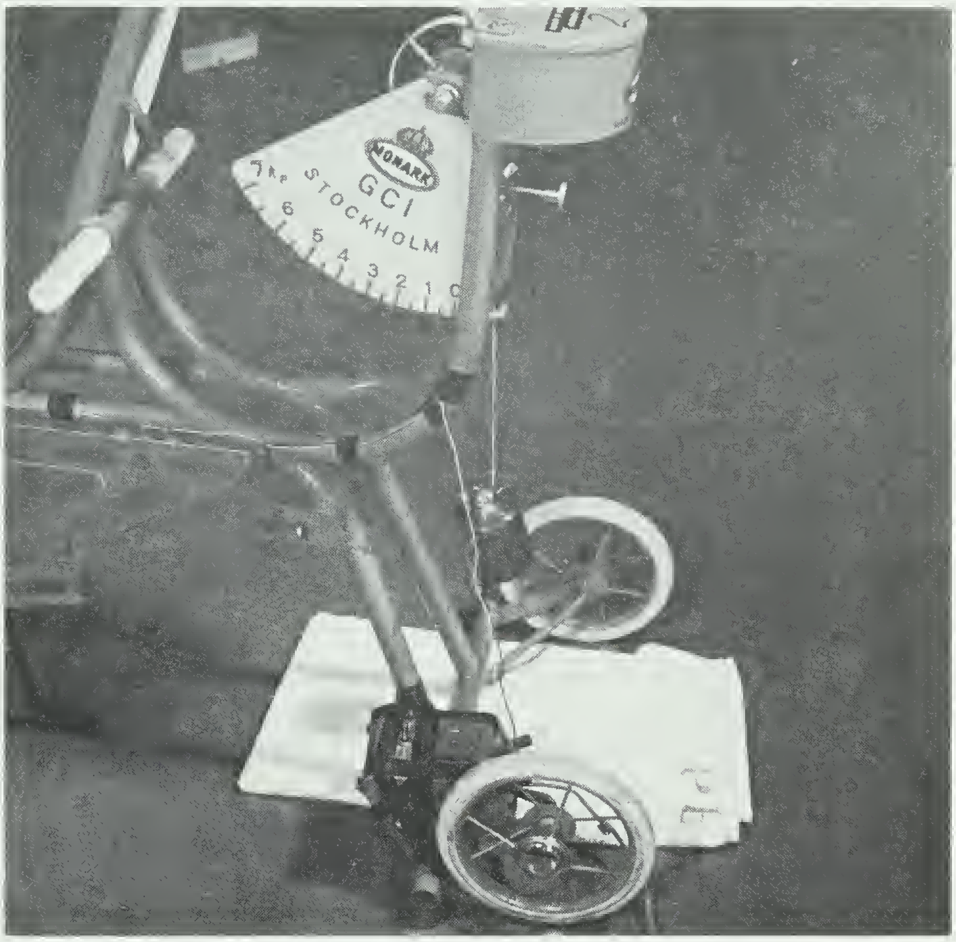

FIGURE 5

CALIBRATION TECHNIQUE FOR MONARK
BICYCLE ERGOMETER USING A 3 KILOGRAM WEIGHT

up to "7-kp".

4. If adjustment was required, it was carried out by moving an adjusting screw which modified the center of gravity of the sinus balance.

Calibration Gases for the Beckman E-2 Oxygen Analyzer and Godart Capnograph Carbon Dioxide Analyzer

This was completed by evaluating the gases used for calibrating the two instruments. The above was accomplished by the Scholander (114) analytical procedure.

Previous to the actual test, a pilot study was undertaken allowing the investigator to become familiar with the test methods and procedures.

The 100 randomly selected subjects were tested over a five week period with a seven day pause between the test-retest. All test procedures and functions were explained to the subjects in an identical manner.

After arriving in the laboratory general subject information was obtained. The subject was then prepared for the test itself. The next step was the performance of the test, where he rode the ergometer at a specific work load for six minutes then rested for five and repeated this procedure until exhaustion. During the work period heart rates were recorded the last five seconds of each minute and the oxygen uptake was taken during the last minute of work. The gas sample was then analyzed for O_2 and CO_2 content. These scores were then recorded and the results calculated. If the subject was unable to complete the six minute work load he then gave a signal to the tester so that the proper procedures could then be followed when obtaining the gas sample.

In order to obtain the above information the following equipment was used; a bicycle ergometer, an electrocardiogram, Douglas bags, a Carbon Dioxide and an Oxygen analyzer, an electric metronome, a one way valve and a nasal clamp (see figures 1, 2, 3, 4). To be certain that the equipment gave accurate scores, calibration techniques were carried out (see figure 5).

CHAPTER IV

RESULTS AND DISCUSSION

Results

Information regarding physical characteristics of individual test subjects is shown in table II.

TABLE II

PHYSICAL CHARACTERISTICS OF TEST SUBJECTS

CHARACTERISTIC	MEAN	STANDARD DEVIATION (SD)	RANGE
Age, yr.	18.97	.30	18-22
Height, in.	69.76	2.4	62.75-74.50
Weight, lbs.	159.21	8.6	108-220

The mean and standard deviation for the MVO_2 test was expressed in liters per minute and was found to be $3.249 \pm .552$. The scores ranged from a low of 2.0451 to a high of 5.0366 l/m. These values were calculated from the scores obtained after the test on the bicycle ergometer.

Table of Norms for MVO_2

The table of norms was derived by recording the MVO_2 readings obtained on the ergometer and then calculating the mean ($\bar{X}$) of the raw scores. The mean ($\bar{X}$) = 50 for both the T-score and standard score, with the step interval of three for the T-score and a step interval of five for the standard score. The standard deviation (S) of the raw scores was calculated by using: $S = \sqrt{\frac{\Sigma x^2 - (\Sigma x)^2/N}{N - 1}}$ and then in turn to calculate the increment for standard scores the following formula was used: standard score $= \frac{6 \times S \times 5}{100} = \frac{3}{10}$ S. To calculate the T-scores this formula was used:

$T = \frac{10 \times S \times 3}{100} = \frac{3}{10} S$. The calculated increment was thus equated for both the T and standard scores by use of the two formulas. After the increment was calculated it was then added or subtracted to the mean to establish the score for each step interval. Table III shows the table of norms that was compiled as a result of scoring first year men ranging in ages 18-22 years old.

TABLE III

MVO_2 BICYCLE ERGOMETER TEST NORMS FOR UNIVERSITY MALES EXPRESSED IN LITRES PER MINUTE

STANDARD SCORE	T-SCORE	MVO_2 IN L/M
	100	6.180
	90	5.628
100	80	5.076
95	77	4.910
90	74	4.744
85	71	4.578
80	68	4.412
75	65	4.246
70	62	4.080
65	59	3.914
60	56	3.582
55	53	3.416
50	50	3.250
45	47	3.084
40	44	2.918
35	41	2.752
30	38	2.586
25	35	2.420
20	32	2.254
15	29	2.088
10	26	1.922
0	23	1.756
	20	1.590
	10	1.038
	0	0

Comparison of VO_2 & HR at 600kpm of U of A Men with Temple University Men

When the comparison was made between the 18 year old group of subjects from University of Alberta and an 18 year old group of subjects from Temple University in Philadelphia (108), the findings revealed no significant difference in the VO_2 and HR at 600kpm (tables IV and V). Similarly, it was also observed that no significant difference in VO_2 was found between the men of these same two institutions, who ranged in ages 20-22 years old (tables IV and V).

TABLE IV

HEART RATE COMPARISONS AT 600 KPM/MIN
BETWEEN PHILADELPHIA AND EDMONTON SUBJECTS

SUBJECTS	AGE	NUMBER OF SUBJECTS	MEAN HEART RATES	SD
PHILADELPHIA	18	50	140±2*	16
	20	33	145±2	14
	22	19	143±4	18
EDMONTON	18	37	137±2.6	16.7
	20	22	139±2.9	13.6
	21-22	5	140±1.9	4.4

*Mean± Standard Error of the Mean

TABLE V

OXYGEN CONSUMPTION COMPARISONS AT 600 KPM/MIN
BETWEEN PHILADELPHIA AND EDMONTON SUBJECTS

SUBJECTS	AGE	NUMBER OF SUBJECTS	MEAN OXYGEN CONSUMPTION	SD
PHILADELPHIA	18	10	1.47±0.06*	0.18
	20-22	11	1.58±0.05	0.18
EDMONTON	18	37	1.57±.09	0.55
	20-22	27	1.60±.004	0.18

*Mean± Standard Error of the Mean

The VO_2 difference in the 18 year old group comparison showed t = .54866 with P = .30 and for the 20-22 year old group t = .4950 and P>.60.

The HR difference between the two groups of 18 year olds, as shown by the t-test, was t = .6415 with a P = .30. The HR difference as shown once again by the t-test was, t = 1.5627 with the P>.10 for the 20-22 year old group. The above figures were calculated from Fisher's Table of t and illustrate the fact that the differences were not significant.

Correlation Coefficients

The correlation coefficient (r) after a test retest, as described previously, for MVO_2 was 0.82 and for MHR at 600 kpm's was found to be 0.77. Table VI gives the means and standard deviation for these two aspects. These correlation coefficients were calculated according to the method described by Edwards (57:2) and Morford (98).

TABLE VI

CORRELATION COEFFICIENTS FOR THE TEST RETEST OF MVO_2 AND MHR

TEST	NUMBER OF SUBJECTS	$\bar{X}MVO_2$	SD	$\bar{X}MHR$	SD
FIRST TEST	17	3.0971$\pm$78	3.24	191$\pm$4.78	19.70
RETEST	17	3.0958$\pm$78	3.22	190$\pm$4.76	19.57

Comparison of Non-smokers with Smokers in MVO_2 & MHR

While the table of norms was being constructed the individuals were categorized into two different groups, smokers and non-smokers. The categorization of these individuals was carried out simply by asking each individual whether he smoked or did not smoke. Each was then placed in the appropriate group. The difference between the smokers and non-smokers

was not significant as it was found that t ≑ .1536. The mean for smokers was 3.2594 l/min. while for the non-smokers the mean was 3.2433 l/m.

The mean MHR for smokers was found to be 190.6 beats per minute while for non-smokers the observed mean MHR was 190.4 beats per minute. Similarly in MHR it can be seen that the difference is not significant. A further breakdown of comparisons for smokers and non-smokers is shown in table VII.

TABLE VII

A COMPARISON OF SMOKERS WITH NON-SMOKERS IN $\bar{X}MVO_2$, $\bar{X}MHR$, $\bar{X}ML/KG/M$, $\bar{X}$ WT (EXPRESSED IN BOTH KG'S AND LBS)

NON-SMOKERS	CIGARETTES	$\bar{X}MVO_2$	$\bar{X}ML/KG/M$	$\bar{X}MHR$	$\bar{X}KG$	$\bar{X}LBS$
TOTAL	SMOKED/DAY					
63	0	3.2433	44.48	190.40	72.92	160.43
SMOKERS						
7	0-5	3.2953	47.42	197.14	68.31	150.29
11	6-10	3.2144	44.62	191.81	72.03	158.48
10	11-15	3.3361	45.03	191.00	74.09	163.00
9	16-25+	3.2150	46.69	186.33	69.59	153.11
TOTAL						
37	1-25+	3.2594	45.75	190.60	71.23	156.71

The table illustrates that all those who smoked had a higher $\bar{X}$ml/kg/m O_2 consumption than the non-smokers. However, when the total number of the non-smokers is compared to that of the total number of smokers, the $\bar{X}$ml/kg/m difference is small. This small difference is also indicated when the $\bar{X}MVO_2$ and the $\bar{X}MHR$ of each is compared. The table does show that the $\bar{X}MHR$ for smokers decreases as the number of cigarettes smoked per day increases. It also indicates that the $\bar{X}MHR$ for non-smokers is higher than for those who smoked more than 16 cigarettes per day. A

correlation coefficient was calculated for MVO_2 and MHR and was found to be +0.04849.

Discussion

Comparison of Mean MVO_2 and MHR of U of A Men to Other Results

A comparison of the results of the numerous studies showed a large discrepancy in the MVO_2 and MHR scores that were obtained. The reasons for these discrepancies are many. However, it seems probable that to some degree, one can surmise the reasons for the results.

Upon scrutinizing the study done by Anderson and Hart (8) it seems probable that the subjects in the study may not have been a normal random sample of the population. The reason for stating this is the fact that the highest MVO_2 was 2.9 l/min with a group average of 2.5 l/min. There are a number of possibilities for such a low MVO_2 score. Their subjects could have been either very young, under 12 years of age, or older subjects, 50 years of age and older, or a group of females or a group of males in very poor physical condition. If their group of subjects consisted totally of any one of the above groups then it is not difficult to understand the scores that were obtained. However, if they had normal young healthy men, their mean and MVO_2 should be much higher as was the case in this present study. On the other hand when comparing the MVO_2 of an intercollegiate athlete from the present study to those of Astrand (16) and Astrand and associates (20), one notes that the MVO_2's compare favourably. One could deduct that the groups studied in the above reported investigations (16, 20) were not indicative of groups of normal individuals but, individuals who may have engaged in a good deal

of exercise or those of well trained athletes.

The mean of 2.5 l/m obtained by Anderson and Hart (8) compare favourably to those scores obtained by Astrand (12) where the MVO_2 was 2.55, 2.43 and 2.14 l/m respectively for 45 subjects 50-64 years old, 22 subjects 55-59 and 6 subjects 60-64 years old. The subjects used by Anderson and Hart (8) could be of the same category as one of those of Astrand (12).

Norris and Shock (102) recorded a mean MVO_2 of 3.02 l/m for 18 and 19 and 20 year old groups which compares favourably to the mean MVO_2 of 3.2490 l/m of this study for men ranging in ages 18-22 years old. Astrand (16) observed that females 14-15 years old or older had a mean MVO_2 of 3.78 l/m which exceeds the means of both Norris and Shock (102) and those presented herein for males ranging in ages 18-22 years old. This can only be construed as a group of well conditioned female athletes while those of the above stated cases were not well trained and conditioned. To substantiate this point, we can take the results obtained by I. Astrand (10) on a group of females 20-29 years of age. In this study she obtained an MVO_2 of 2.23 l/m for the above age group. If we compare the results of (10) 2.23 l/m to those of (16) 3.78 l/m we find a vast difference. The most probable reason for this discrepancy in scores would be the fact that one group was in better physical condition than the other group. It would seem that a training program was devised to keep the group with the high MVO_2 in good physical condition, because it is difficult to perceive that girls without conditioning could obtain such a high MVO_2. In fact it is difficult for men to attain this 3.78 l/m MVO_2 without doing some training to increase the PWC of the body.

After observing the mean MHR's obtained by numerous authors (16, 86, 102, 107, 124) one can say that the mean MHR of 190.5 recorded in this study is similar to those obtained by the above authors. The means obtained by the aforesaid authors varied from 190 to 205 beats per minute where the subjects were of similar age, 18 to 22 years old, it was found by Strandell (124) that mean MHR was between 190-195 while Norris and Shock (102) found the mean MHR for a 20 year old group to be 200 beats per minute. In the studies done by Astrand (16), Robinson (107), Kramer and Lurie (86) and others quoted in (86) show that the mean MHR's are higher than those obtained in this study as well as in Strandell's (124) study. The most obvious reason for the higher heart rates seems to be the fact that in all cases of (16, 86, 107 and the others cited in 107) the subjects were younger and ranged in ages 6 to 19 years of age. This fact is verified in the study done by Astrand (16), as he showed that the average MHR values for subjects under 20 years of age lay between 202 and 211 beats per minute independent of age and sex, while for adults the mean values obtained were 194 for males and 198 for females.

The difference in MHR's between two 20 year old groups would be due primarily to the different test and testing techniques involved, as a result the observations would be different showing somewhat of a discrepancy. Thus a difference between both that of Norris and Shock (102) mean MHR of 200 beats per minute for 20 year olds and those of this study with a mean MHR of 190.5 beats per minute.

In the case of maximal results in this study there is no doubt that each individual reached his MVO_2 and MHR as he was run to exhaustion, rested for 5 minutes and then re-run to exhaustion on the next work load.

During the test the individual worked to exhaustion until his MVO_2 levelled off or dropped below his maximal obtained in the previous work load. This in itself suggests that there is no possibility of anything but a maximal effort being obtained.

<u>The Table of Norms for MVO_2</u>

Test scores have no absolute significance. It is obvious, for example, that a score of 50 on a test of only 50 items may have different implications from a score of 50 on a test of 100 items. Even if we express a subject's score in percentage terms, we may have said very little about his ability; for if, on a given test, all the subjects get 100% of the items correct, there is no distinction in a perfect score. On the other hand, on a more difficult test, a score of only 70% might indicate unusual ability. The implication being that a score takes on significance only by comparison with other scores and that its significance is relative not absolute.

Ultimately the prime purpose of a normative table is to establish a set of scores which is indicative of a certain group of individuals. Once the table has been established it allows one to make the comparison of other scores, thereby giving a relative indication as to the standing of an individual to a group of similar individuals, in a specific test situation. Theoretically an ideal normative table has 68.26% of the total scores in the first deviation above and below the mean, 95.4% $\mp$ 2 σ, 98.8% $\mp$ 2.5 σ and 99.74% $\mp$ 3 σ above or below the mean. Smith (121:16) stated:

> There is no apriori reason why we should expect the distribution of scores for any human trait to follow the normal probability curve. But it has happened so often in the past, we are a little suspicious when we get any marked deviation from it.
> ...In any case, before we go far with an experiment or a testing program, there is a clear need to check, by means of a frequency polygon or histogram, to see whether we are dealing with a bimodol, seriously skewed, or otherwise irregular distribution.

Cumbee (43:81) stated that: "Authorities rather generally agree that if a sample has 30 or 40 units, then for all practical purposes the sample may be considered a large sample." However, she goes on to fortify the above statement by cautioning that the distribution of the trait in the population should be considered in determining sample size. In other words, if the trait is highly skewed in the population, a large sample is needed.

Figure 6 shows a histogram with the distribution of scores obtained from this study. When one studies the histogram, a normal curve pattern seems to indicate itself. In other words no seriously skewed or otherwise irregular distribution presents itself. Upon further analysis of the histogram one can recognize the 53 per cent of the scores are found below the mean ($\bar{X}$) and 47 per cent are found above the mean ($\bar{X}$). This, plus the fact that the range of scores is not extreme seems to indicate that the scores are in a normal pattern. This is further brought out by grading "On the Curve" which makes use of the principle of relative standing. Ideally, when this procedure is applied to a normal distribution of scores it gives approximately 7 per cent A's, 24 per cent B's, 38 per cent C's, 24 per cent D's, and 7 per cent E's. The percentage comparisons of the ideal normal curve and actual scores obtained in this study are shown in table VIII.

TABLE VIII

GROUP COMPARISONS OF AN IDEAL NORMAL CURVE AND ACTUAL SCORES OBTAINED EXPRESSED IN PERCENTAGE

GROUPS	A	B	C	D	E
IDEAL PERCENTAGE	7	24	38	24	7
ACTUAL PERCENTAGE	4	31	33	22	10

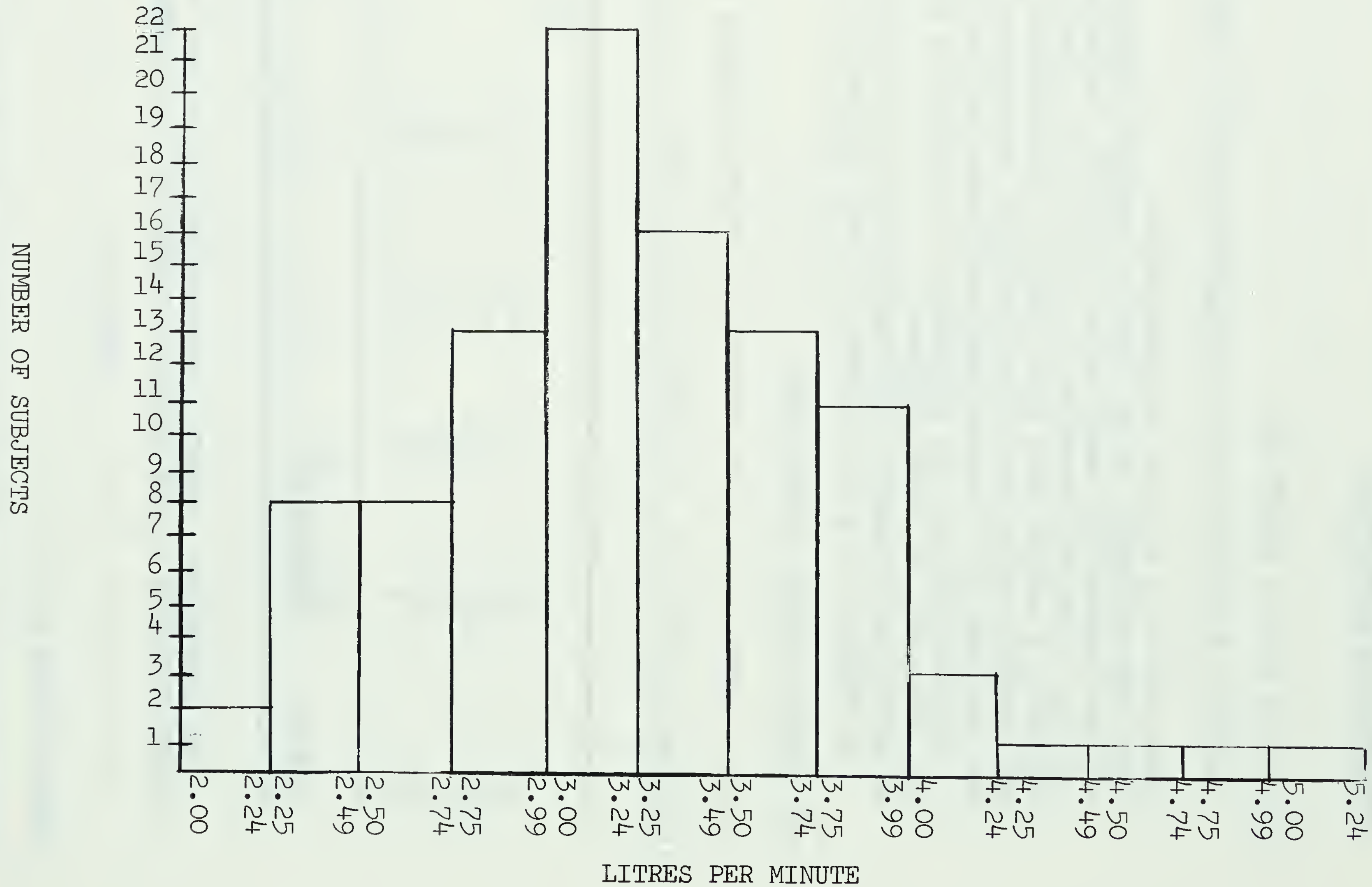

FIGURE 6

FREQUENCY DISTRIBUTION OF MVO'S IN L/M

The results in table VIII were further analyzed to calculate their "Goodness of Fit" test for the actual scores obtained. The results are shown in table IX.

TABLE IX

CALCULATIONS OF x^2 FOR TESTING GOODNESS OF FIT BETWEEN OBSERVED AND THEORETICAL (NORMAL) DISTRIBUTIONS OF 100 MVO_2'S IN PWC

GRADES	FREQUENCIES fo	ft	(fo-ft)	$(fo-ft)^2$	$\frac{(fo-ft)^2}{ft}$
A	4	7	-3	9	1.29
B	31	24	+7	49	2.04
C	33	38	-5	25	0.66
D	22	24	-2	4	0.17
E	10	7	+3	9	1.29
					x^2 = 5.45

If Fisher's Table of x^2 is observed for the value of 5.45 for which d.f. = 4, one finds that it lies between the values for which P = .90 and P = .10. Smith (121:89) stated that:

> In general, if P lies between .10 and .90 there is no reason to reject the hypothesis being tested; but if P is less than .02 the hypothesis is pretty dubious.
>
> The criterion for the acceptance or rejection of hypothesis are arbitrary but a conventional rule draws the line at P = .05 and regards a hypothesis as inadequate or unsatisfactory for values of P smaller than this (That is, for values of x^2 larger than the value corresponding to a P of .05). It should be pointed out that excessively small values of P (say, larger than .95), occur just as rarely on the basis of sampling variations as very large values of x^2, for true hypothesis.

The above quotation clearly illustrates that the sample for the table of norms is truly a normal one.

Validity and Reliability

Chapter II of the study has already shown the high reliability and

validity of MVO_2 and MHR testing, thus indicating very good reproducability and also revealing good relationship between several test measurements and the criterion.

The reliability scores of MVO_2 range from r = .63 to r = .97 whereas the score obtained in the present study is r = .82. Thus we can see that the reliability score of this study compares rather favourably with the observed range of scores presented herein. The reliability score range for MHR was r = .67 to r = .71 while the score for this study was r = .77. In this case we can see that the MHR of this study is above those reported in the literature herein.

Hettinger, et al (72) and Glassford (67) found the validity of MVO_2 when compared to other test criterion to range from .05 to .001 levels of confidence. This indicates that the validity of the MVO_2 test is very high.

Comparative Study of Smokers and Non-smokers

The studies reported on smoking were not difficult to analyze in terms of the effects on the human body. A cursory analysis of the results shows a contradiction, in that some studies showed that smoking had very little influence on performance while others indicated a definite effect on the body. However, a point in case is, what kind of a smoking study was it? Did the study involve the complete human body or just the hand? An analysis of the studies will indicate that only one conclusion can be drawn and that a cursory glance at studies on smoking is a misleading one.

Several experimenters (61, 110) have shown that when the body is at rest cigarette smoking reduced body temperature in the extremities. On

the other hand, an increase in body temperature was found by Johnson and Short (80, 118) and Goddard and Voss (68). However numerous authors (25, 33, 89, 92, 93, 136, 139, 140) found that vasoconstriction of the peripheral blood vessels occurred after smoking. These authors had helped to fortify the statement that body temperature in the extremities was lower because of cigarette smoking. Au contraire, Mulinos and Shulman (119) and Smithwick (122), stated that vasoconstriction through the finger occurred after deep breathing, immersion of the contralateral hand in cold water, or a loud noise, or after unpleasant thought. Does this then make it plausible that factors other than smoking could possibly have caused vasoconstriction in the peripheral vessels of the extremities? It does, but it seems highly improbable that during the investigations of (25, 33, 89, 92, 93, 136, 139, 140) that any of the adverse conditions would be prevalent, unless there was a specific desire to present these stimuli to obtain the results of (119, 122). From this analysis one observes that smoking does indeed cause vasoconstriction of the peripheral blood vessels. Therefore, recognizing this fact, how is it possible to state that smoking does not affect the individual or his physical performance?

Other investigators (68, 73, 99, 110, 118) observed that heart rate increased, but that the increase was not significant. It was also noted by a large number of experimenters (25, 33, 73, 89, 92, 93, 99, 110, 118, 139, 140) that blood pressure increased as a result of smoking. These studies in both cases show that smoking does increase the work of the heart and is therefore harmful.

Levy, et al (90) concluded that with the exception of susceptible

persons, cigarette smoking caused slight changes in circulation and did not increase significantly the work of the heart. Several authors (4, 48, 56) as well as this study, support the idea that cigarette smoking caused slight changes in circulation and did not increase significantly the work of the heart.

In studies done by two investigators (48, 56) it was found that many highly skilled runners who finished first or placed in the top were smokers. In a study done in 1958 (4) on athletes in the British Empire Games, it was found that 1/3 of the 285 athletes smoked. The degree to which these men smoked is not known, but it has been shown that very good athletes also smoke and are still able to perform well. The question that arises here is, would these same athletes perform better if they did not smoke? This query may be answered best by studying the effects of smoking upon pulmonary permeability, diffusing capacity and oxygen consumption. It seems that it is in this area that the effects of smoking would be the greatest because of the direct contact smoke has with the respiratory system. Once the effects of smoking are known in the lung area then researchers may proceed to study the effects on muscles or on performance of specific tasks.

Karpovich and Hale (82), in testing 8 habitual smokers and 5 non-smokers found that the average riding time on a bicycle ergometer was better when they did not smoke than when they did smoke. The difference found, was not significant. The question that causes uncertainty here is, how did he test both the smoking and non-smoking group in the two situations? When they tested the non-smoking group, were there conditions identical with those of the habitual smokers? When the group quit smo-

king how long did the investigators wait to test in the non-smoking condition? The most conspicuous query is how did he get the non-smokers to engage whole heartedly in the experiment, as smoking was against their principles? When these problems are posed and analyzed the results seem dubious.

Reeves and Morehouse (105), in their study, endeavoured to surmise the effects of smoking on habitual smokers under two conditions: (a) a non-smoking period two hours prior to the test, and (b) inhaling 2.7 litres of smoke from one cigarette. Four items were administered and tested under both of the above conditions; they included speed, strength, agility and endurance. They found that smoking did not have any influence upon the performance of the designated tests. It was also shown that if a person was a habitual smoker, no difference was observed if he smoked immediately before or whether he abstained from smoking for a few hours before performing the tests. Physiologists are of the opinion that a two hour abstinance would not change body functions or chemistry to any great degree in a habitual smoker. Thus one sees that the assumptions of the experimental design were too presumptuous.

It would be more realistic to consider the effects of smoking upon the nervous system by studying it first, then see if the nervous system is affected when it is found in conjunction with the other bodily systems. The same argument, the study of specific effects on specific systems, can be used for numerous other studies (7, 83, 137) done on smoking. These investigators were attempting to investigate areas with conditions and techniques not sophisticated enough to determine any differences in performance and which we simply do not have enough knowledge about. There-

fore, the results obtained by them stand in a rather dubious position. Until testing techniques are refined and more is known about the effects of smoking on the body, results from such studies as (83, 123, 137) should be considered with caution. If the problems in these studies were more defined and delimited it is felt that the results would possibly be more definitive or positive. At present, the conclusions drawn by these investigators seem dubious because of the many variables that could cause the same effects that have been attributed as a result of smoking.

It is interesting to note that a number of researchers (36, 71, 82, 90, 99) who, could measure more accurately what they set out to measure, and used a more refined or sophisticated technique did find differences between smokers and non-smokers. The differences were not significant but nonetheless non-smokers performed better and had lower cardio-circulatory responses than did the smokers.

In the present study the differences in smokers and non-smokers was not statistically significant in $\bar{X}MVO_2$ and $\bar{X}MHR$. However, it was presumed that the reason for no significant differences existing between smokers and non-smokers was, because the group of non-smokers was smaller than the smoking group. As a result it was not a true comparison because of the fewer number of smokers. If the groups were of equal size it is possible that a greater difference would have been found between the groups.

Discussion of Factors that Influence MVO_2 and MHR

Numerous factors influence MVO_2 and MHR. However, only four factors are considered here namely, smoking, training, age and environment (referring to temperature) and their effects on the two aforenamed physiological

parameters.

Effect of Smoking on MVO_2 and MHR

In the present study where the comparison was made between smokers and non-smokers no statistically significant difference was found in the MVO_2 and MHR. However, when this comparison was carried further it was found that the $\bar{X}$MHR of individuals that smoked more than 16 cigarettes per day was 186 BPM compared to 190 BPM for non-smokers. Table IV showed that, as the number of cigarettes smoked per day increased, correspondingly the $\bar{X}$MHR decreased. When the $\bar{X}MVO_2$'s in Table IV are compared the same results do not present themselves. In some cases the $\bar{X}MVO_2$ of non-smokers was greater while in other instances it was smaller.

Effect of Training on MVO_2 and MHR

Although training with regards to MVO_2 and MHR was not a sub-problem in this study, it was of concern for comparative purposes. Numerous authors (17, 34, 41, 62, 64, 74, 78, 127, 128, 135) illustrate that training definitely increases both MVO_2 and MHR. Regardless of whether training is short or long term or intermittent it improves the PWC of an individual. When the mean MVO_2 and MHR results of two studies carried out by Astrand (16, 17) were analyzed and compared to those in this study a great difference was noted. This large discrepancy was attributed to the fact that in Astrand's (17) study, he points out the average MVO_2 to be 58.6 ml/kg/min while the highest reported $\bar{X}MVO_2$ in the present study was 47.42 ml/kg/min. Others (106, 108, and Morse cited in 86) had MVO_2's similar to those reported in this study.

Effects of Age on MVO_2 and MHR

Numerous authors (10, 11, 12, 16, 42, 51, 52, 54, 55, 63, 72, 102, 107, 124, 125) have shown that both MVO_2 and MHR decrease with an increase in age. This decrease may occur after 40 years of age in men and the older an individual becomes the lower is his MVO_2 and MHR. However, when measurements have been taken on individuals ranging in ages 18 to 22, the range of scores seems to be fairly consistent especially if the samples are similar. That is to say, one does not compare the results of a well trained group to that of a sedentary group and expect the same scores.

When the comparison was made between the subjects from this study with those of Rodahl, et al (108), the results showed no statistically significant differences.

However, the point here is, that little difference exists in the range of scores for subjects ranging in ages 18 to 22 years of age.

Effect of Environment on MVO_2 and MHR

In the present study the temperature range was 68-76°F. According to numerous authors (32, 38, 39, 111, 126, 132) the temperature range of this study would not affect the PWC. They are of the opinion that PWC decreases when environmental temperature is much warmer than the maximum of this study. This would then ostensibly indicate that environment or, more specific, temperature did not affect either MVO_2 or MHR of any of the subjects.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

This study was undertaken primarily to determine the PWC of first year men at the University of Alberta in Edmonton. This was done by determining their MVO_2 and establishing a table of norms from the scores obtained. This was accomplished by using the Astrand Bicycle Ergometer Test for MVO_2.

The test consisted of a work period lasting six minutes and was alternated with a five minute rest period. As each new work period started the resistance was increased 300 kpm until the subject could no longer keep the pedalling rate at the desired 50 cycles per minute or, until exhaustion ensued. During each work period, a sample of gas was taken for the last minute. Heart rates were taken before the work period started as well as during the last five seconds of each minute of work. In this way MHR's were obtained.

The secondary aspects of the study considered included: a comparison of the non-smoking and smoking subjects as to MVO_2 and maximal heart rate; measuring pulse response to fixed work loads; and a comparison of the results of this study to those of Rodahl, et al (108) from other countries.

In order to procure the information for the study numerous types of equipment and apparatus were used. The test was carried out by using a Swedish Bicycle Ergometer Monark CI, Douglas Bags, Electrocardiogram, Volume and Vacuum pumps, a Beckman O_2 analyzer, a Godart CO_2 analyzer, along with a stop watch, electric-metronome as well as adjustable head-gear.

A random sample of one hundred healthy male students from the University of Alberta participated in the study. The age range was from 18 to 22 years old.

When establishing the table of norms statistically, the mean and standard deviation as well as the increment were calculated and then added or subtracted to give the desired results (24, 121).

The other statistical procedures that were used to analyze the data were the t-test for significance and the Product-Moment correlation coefficient to test for reliability.

Conclusions

1. The table of norms has given a valid estimate of the MVO_2 performance of a random sample of first year men ranging in ages 18 to 22 at the University of Alberta, Edmonton, in the academic year 1963-64.

2. No statistically significant difference was shown to exist in $\bar{X}VO_2$ between U of A men in Edmonton at age 18, at 600 kpm, and the $\bar{X}VO_2$ of a similar group of individuals from Temple University of Philadelphia, U.S.A.

3. No statistically significant difference was found between the VO_2's of U of A men in Edmonton and Temple University men ranging in ages 20-22 years old. The work load once again was 600 kpm.

4. Similarly it was shown that no statistically significant difference existed in $\bar{X}HR$ between U of A men in Edmonton, at age 18 and a work load of 600 kpm, and $\bar{X}HR$ of a similar group of individuals from Temple University of Philadelphia, U.S.A.

5. When the $\bar{X}HR$ of these same two samples were compared, again at

600 kpm, for men aged 20-22 years old, it was found that no statistically significant difference occurred.

6. A comparison in $\bar{X}MVO_2$ of smokers and non-smokers was made, and the results showed no statistically significant difference between the two groups.

7. Similarly it was found that the $\bar{X}MHR$ of smokers and non-smokers when compared, showed no statistically significant difference.

8. When the $\bar{X}MHR$ of non-smokers was compared to those who smoked more than 16 cigarettes per day it was found that the non-smokers had a higher $\bar{X}MHR$.

9. When the $\bar{X}MHR$ of non-smokers was compared to those who smoked between 0 and 5 cigarettes per day it was found that those who smoked had a higher $\bar{X}MHR$ than the non-smokers.

As a result of this study a number of questions arose. It was felt that the following recommendations would help to clarify knowledge in different areas of work on the bicycle ergometer.

Recommendations for Additional Study

1. Carry out a study to note the MVO_2 performance on a bicycle ergometer before and after engaging in a weight training program centered on increasing the strength of the legs.

2. Endeavour to discover the PWC performance of urban subjects (city), rural urban (towns) and rural subjects (on farms), as measured by the MVO_2 test and compare them.

3. Attempt to examine more fully the MVO_2 and MHR performances of 100 smokers in each of these groups, 0-5, 6-10, 11-15 and 16 or more, and

compare them to an equal number of non-smokers.

4. Further attention should be directed to make an international comparative study of PWC using MVO_2 and MHR tests, so that accurate comparison can be made.

5. Efforts should be made to study the PWC when comparing a group which rides a bicycle regularly with other groups engaged in several different types of physical activity, of equivalent difficulty, so that the effects may be observed.

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APPENDIX A

STATISTICAL TREATMENT

In order to establish the table of norms these steps were followed:

1. The mean of the raw scores was calculated.

2. The mean was then equated to the mean score of 50 for both the standard score and T-score.

3. The standard deviation of the raw scores was calculated by use of the following formulas (24).

$$s = \sqrt{\frac{\Sigma x^2 - (\Sigma x)^2/N}{N - 1}}$$

$$\text{Increment} = \frac{V \times S \times S.1}{100}$$

V = variable equalizer

S = standard deviation

S.l. = step interval

$$\text{Standard score} = \frac{6 \times S \times 5}{100} = \frac{3}{10}\,S$$

$$\text{T - score} = \frac{10 \times S \times 3}{100} = \frac{3}{10}\,S$$

4. The increment was then added or subtracted from the mean and then each consecutive answer thereafter.

To calculate for significance by use of the t-test the following formulas were used (57):

The sum of x^2 was calculated by:

$$\Sigma x^2 = \Sigma x^2 - \frac{(\Sigma x)^2}{n}$$

Variance of a population was estimated by:

$$s^2 = \frac{\Sigma x^2}{n - 1}$$

Standard error of the mean was given by:

$$S\bar{x} = \frac{s}{\sqrt{n}}$$

The standard error of the difference between the means was estimated by:

$$s(x_1 + x_2) = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

When testing for significance was carried out, the independent t-test was used;

$$t = \frac{(\bar{X}_1 - \bar{X}_2)}{s(\bar{x}_1 - \bar{x}_2)}$$

Degrees of freedom = $N_1 + N_2 - 2$

The Product-Moment correlation coefficient method was used to calculate the correlation by the following formula:

$$r = \frac{N\Sigma XY - (\Sigma X)\ (\Sigma Y)}{\sqrt{\left[N\Sigma X^2 - (\Sigma X)^2\right]\ \left[N\Sigma Y^2 - (\Sigma Y)^2\right]}}$$

To substantiate the reliability correlation coefficient the Spearman-Brown prophecy formula was used (98):

$$r + t = \frac{2r}{1 + r}$$

APPENDIX B

INDIVIDUAL SCORE SHEET

GAS ANALYSIS SHEET

300 KPM
600
900
1200
1500
1800
2100

NAME ____________________

DATE ____________________

T = __________ °C

B.P. = __________ mm. Hg

Factor = __________

Heart Rate per Minute

1 2 3 4 5 6

FeO_2 = __________ X $\frac{2.5}{1000}$ = __________ F_IO_2 = 20.94

FeO_2 = __________ (corr.) F_ICO_2 = 00.03

$FeCO_2$ = __________ F_IN_2 = 79.03

FeN_2 = __________

V_EATPS = __________ l./min.

V_ESTPD = __________ X __________ = __________ l./min.

V_ISTPD = __________ X $\frac{\text{\_\_\_\_\_\_\_\_\_\_}}{.7903}$ = __________ l./min.

VO_2 = (__________ X .2094) - (__________ X __________) = __________ l./min.

VCO_2 = (__________ X ______) - (__________ X .0003) = __________ l./min.

R. Q. = ____________________

Smoker __________ Number __________

Health (general) ____________________

Height ____________________ inches

Weight __________ pounds __________ kilograms

Birthday ____________________

APPENDIX C

RAW SCORES

INFORMATION REGARDING PHYSICAL CHARACTERISTICS OF INDIVIDUAL SUBJECT

SUBJECT	AGE	WEIGHT IN POUNDS	SMOKER NUMBER SMOKED PER DAY 1 TO 5	6 TO 10	11 TO 15	OVER 15	NON-SMOKER	HEIGHT IN INCHES
1	20	184.75					X	69.00
2	20	193.00		X				70.50
3	19	160.00	X	CASUAL PIPE				72.00
4	19	159.00				X		69.00
5	19	179.00					X	69.00
6	18	164.50					X	71.00
7	18	177.00					X	69.25
8	19	145.00					X	69.00
9	18	143.00					X	68.00
10	18	189.25					X	74.25
11	19	170.75					X	74.50
12	19	172.00				X		73.00
13	19	191.00					X	71.00
14	19	179.50		X				71.50
15	19	174.50					X	72.25
16	18	174.00			X			70.50
17	20	160.75					X	70.50
18	20	168.25	X	CASUAL				68.50
19	21	161.00					X	69.00
20	20	140.00					X	68.25
21	18	150.50					X	69.25
22	18	141.00					X	72.00
23	20	169.25					X	69.00
24	20	184.50			X			71.75
25	18	220.00					X	72.50
26	19	154.75				X		72.50
27	18	176.00					X	70.00
28	19	158.75					X	72.00
29	18	154.50			X			71.50
30	19	108.00					X	62.75
31	19	189.75					X	74.50
32	18	178.75					X	72.25
33	18	163.50	X	CASUAL				73.00
34	19	156.00					X	73.00
35	18	151.25					X	71.00
36	20	160.75		X				69.75
37	21	153.75					X	71.50
38	19	149.75		X				69.00
39	18	143.00					X	66.00
40	18	145.75					X	70.00
41	18	150.00			X			69.50
42	19	139.25			X			69.00
43	19	185.00		X				69.00
44	18	156.00					X	68.25
45	18	158.00					X	70.00

SUBJECT	AGE	WEIGHT IN POUNDS	SMOKER NUMBER SMOKED PER DAY 1 TO 5	6 TO 10	11 TO 15	OVER 15	NON-SMOKER	HEIGHT IN INCHES
46	19	173.50			X			70.00
47	18	201.00					X	70.50
48	20	143.25			X			69.50
49	20	151.50			X			68.00
50	18	148.25	X					69.00
51	20	155.00					X	69.25
52	19	157.00					X	68.25
53	22	186.25					X	70.25
54	20	163.75					X	71.00
55	19	180.00				X		71.25
56	19	181.00					X	73.00
57	20	155.50				X		71.75
58	18	161.00		X				70.50
59	20	154.25					X	73.25
60	18	171.50					X	71.25
61	18	155.50					X	71.00
62	18	154.50					X	67.00
63	19	154.50					X	67.00
64	20	153.75					X	68.25
65	19	145.00					X	65.00
66	18	151.00			X			71.00
67	20	167.50					X	67.25
68	19	208.50			X			73.50
69	18	169.00				X		70.00
70	18	143.75					X	69.50
71	20	130.00	X					71.25
72	19	193.00					X	72.50
73	19	168.34					X	73.50
74	19	142.50		X				70.00
75	20	180.00					X	68.25
76	19	151.50					X	68.50
77	19	141.00		X				70.00
78	18	145.50					X	68.50
79	18	110.00				X		66.00
80	18	124.00					X	66.00
81	18	182.00					X	67.50
82	18	132.00					X	64.50
83	20	151.50	X					67.00
84	20	132.00					X	66.25
85	18	165.00					X	66.50
86	19	147.75		X				68.25
87	18	153.00					X	70.50
88	18	137.25					X	68.75
89	19	149.25				X		67.00
90	20	168.25		X				68.50
91	20	118.00					X	63.50
92	19	154.00					X	68.50
93	21	129.50				X		67.25
94	19	130.50	X					73.00

SUBJECT	AGE	WEIGHT IN POUNDS	SMOKER NUMBER SMOKED PER DAY 1 TO 5	6 TO 10	11 TO 15	OVER 15	NON-SMOKER	HEIGHT IN INCHES
95	18	167.75					X	70.25
96	18	174.50					X	70.50
97	22	152.75					X	73.50
98	19	124.75		X				67.25
99	19	148.50					X	71.25
100	19	147.00					X	66.00

RAW SCORES FOR THE
ASTRAND BICYCLE ERGOMETER
MAXIMAL OXYGEN CONSUMPTION TEST

SUBJECT	WORK LEVEL EXPRESSED IN KILOPOND METERS PER MINUTE 300	600	900	1200	1500	1800	2100
1.							
$\%O_2$	15.71	14.79	14.89	16.05	16.54	17.21	16.68
$\%CO_2$	4.50	4.80	4.90	4.10	3.90	3.25	2.85
V_ESTPD	25.11	30.13	43.52	70.67	107.79	149.84	97.62
VO_2	1.36	1.96	2.88	3.60	4.92	5.78	4.53
MHR	136	143	158	180	204	209	200
2.							
$\%O_2$	18.05	17.19	16.63	16.74	17.25	17.55	17.50
$\%CO_2$	2.85	3.35	3.75	3.80	3.55	3.30	2.95
V_ESTPD	46.35	52.94	64.76	77.08	121.80	142.44	155.89
VO_2	1.35	2.04	2.89	3.32	4.55	4.87	5.58
MHR	117	130	145	173	187	195	191
3.							
$\%O_2$	16.85	17.07	17.02	16.39	16.06	17.20	17.20
$\%CO_2$	3.20	3.20	3.40	3.80	3.80	3.50	2.90
V_ESTPD	37.46	52.04	57.99	81.71	100.34	106.09	98.09
VO_2	1.622	2.108	2.36	4.03	5.190	4.04	3.894
MHR	123	136	161	187	200	195	180
4.							
$\%O_2$	16.63	16.43	15.78	16.60	17.70	17.73	
$\%CO_2$	3.70	3.90	4.50	4.05	3.35	2.35	
V_ESTPD	24.36	37.98	44.66	79.38	111.91	143.12	
VO_2	1.089	1.775	2.386	3.51	3.60	4.929	
MHR	105	125	155	187	187	180	

$\%O_2$ - Percentage of oxygen in the expired air.
$\%CO_2$ - Percentage of carbon dioxide in the expired air.
V_ESTPD - Total volume of gas expired at standard temperature and pressure, dry.
VO_2 - The amount of oxygen consumed.
MHR - Maximal Heart Rate.

SUBJECT	300	600	900	1200	1500	1800	2100
5.							
$\%O_2$	16.34	14.68	13.68	14.44	16.14	16.83	15.18
$\%CO_2$	4.05	5.00	5.70	5.20	4.40	3.85	3.85
V_ESTPD	24.56	25.01	33.07	45.02	95.99	102.75	46.69
VO_2	1.667	1.651	2.539	3.196	4.716	4.30	3.1176
MHR	107	122	150	176	195	191	180
6.							
$\%O_2$	15.70	15.03	15.18	15.90	16.16	15.44	
$\%CO_2$	4.10	4.70	4.70	4.30	3.70	3.45	
V_ESTPD	18.31	28.69	45.02	76.06	63.67	77.40	
VO_2	1.02	1.79	2.72	3.78	3.23	4.68	
MHR	106	129	155	184	187	184	
7.							
$\%O_2$	17.88	16.85	16.23	16.53	17.30	16.48	17.65
$\%CO_2$	3.10	3.60	3.90	4.20	3.40	2.90	2.30
V_ESTPD	38.43	40.11	52.62	70.05	99.19	95.28	85.33
VO_2	1.1738	1.694	2.5998	3.1337	3.6817	4.649	3.0376
MHR	125	132	150	184	195	187	
8.							
$\%O_2$	15.25	13.62	14.80	15.88	15.69		
$\%CO_2$	3.70	4.60	4.60	3.90	3.20		
V_ESTPD	25.87	32.21	53.64	85.13	73.53		
VO_2	1.61	2.59	3.52	4.58	4.07		
MHR	117	144	169	184	173		
9.							
$\%O_2$	15.31	14.75	14.64	15.69	16.40	16.46	
$\%CO_2$	4.10	4.80	5.10	4.70	4.40	3.50	
V_ESTPD	16.11	24.58	37.79	65.52	83.22	95.46	
VO_2	.974	1.61	2.50	3.54	3.81	4.53	
MHR	100	132	166	187	187	187	

SUBJECT	300	600	900	1200	1500	1800	2100
10.							
$\%O_2$	16.68	16.88	16.64	17.43	17.41	17.41	
$\%CO_2$	3.70	3.60	4.10	3.60	3.20	2.80	
V_ESTPD	28.52	53.36	58.72	103.21	124.55	96.20	
VO_2	1.26	2.24	2.56	3.62	4.51	3.59	
MHR	105	127	158	185	187	189	
11.							
$\%O_2$	16.70	15.58	15.35	15.45	16.29	16.68	16.43
$\%CO_2$	3.60	4.40	4.90	5.0	4.40	4.05	3.50
V_ESTPD	31.06	32.86	44.80	61.67	92.99	104.16	56.99
VO_2	1.38	1.83	2.62	3.63	4.38	4.50	2.70
MHR	115	136	155	180	195	187	187
12.							
$\%O_2$	14.98	13.80	13.80	16.43	17.35	17.08	
$\%CO_2$	4.40	5.30	5.70	4.30	3.10	2.80	
V_ESTPD	16.56	24.45	36.76	80.78	119.89	78.57	
VO_2	1.056	1.79	2.77	3.69	4.47	3.26	
MHR	93	115	149	184	173	166	
13.							
$\%O_2$	16.45	16.46	16.95	16.99	17.25	16.46	
$\%CO_2$	3.85	4.20	3.85	3.67	3.40	3.25	
V_ESTPD	30.19	38.63	63.50	84.85	90.01	92.46	
VO_2	1.41	1.76	2.56	3.44	3.70	4.45	
MHR	115	129	155	173	180	180	
14.							
$\%O_2$	15.90	15.90	15.17	16.01	16.60	17.18	
$\%CO_2$	4.10	4.20	4.95	4.55	4.30	3.15	
V_ESTPD	21.63	34.80	42.07	66.10	90.25	113.02	
VO_2	1.15	1.83	2.52	3.32	3.93	4.44	
MHR	105	125	150	187	200	191	

SUBJECT	300	600	900	1200	1500	1800	2100
15.							
$\%O_2$	16.40	16.18	15.83	16.00	16.21	16.85	17.28
$\%CO_2$	3.40	4.20	4.60	4.90	4.30	4.10	2.80
V_ESTPD	22.08	34.68	46.39	63.34	86.52	108.04	107.02
VO_2	1.07	1.71	2.44	3.14	4.22	4.42	4.17
MHR	105	120	135	170	200	200	196
16.							
$\%O_2$	18.43	13.51	15.37	15.51	17.28	16.84	
$\%CO_2$	2.50	4.70	5.00	4.80	3.30	2.80	
V_ESTPD	57.56	25.55	37.96	58.68	116.99	66.55	
VO_2	1.45	2.08	2.18	3.29	4.40	2.96	
MHR	115	125	145	167	187	180	
17.							
$\%O_2$	15.72	15.93	15.88	16.24	17.25	17.16	
$\%CO_2$	4.00	4.80	4.80	4.20	2.50	2.90	
V_ESTPD	20.07	32.43	45.96	73.75	109.11	70.77	
VO_2	1.11	1.65	2.361	3.57	4.38	2.84	
MHR	113	133	163	187	187	180	
18.							
$\%O_2$	16.39	16.09	16.16	16.45	16.79	16.94	
$\%CO_2$	4.15	4.10	4.35	4.25	4.00	3.10	
V_ESTPD	38.73	40.17	55.05	82.83	102.39	70.43	
VO_2	1.81	2.03	2.70	3.78	4.29	2.99	
MHR	145	155	170	200	204	200	
19.							
$\%O_2$	16.75	15.10	16.19	15.64	16.70	17.57	17.45
$\%CO_2$	4.00	4.80	5.00	5.20	4.70	4.10	3.20
V_ESTPD	21.94	28.55	43.50	54.21	83.83	134.94	75.29
VO_2	.932	1.75	2.05	2.89	3.46	4.29	2.69
MHR	117	122	145	173	200	200	195

SUBJECT	300	600	900	1200	1500	1800	2100
20.							
$\%O_2$	16.03	15.65	15.45	17.53	17.82	17.77	
$\%CO_2$	3.60	4.60	4.80	3.50	2.80	2.20	
V_ESTPD	23.07	34.67	46.48	108.31	133.29	107.36	
VO_2	1.21	1.90	2.64	3.67	4.281	3.69	
MHR	122	145	173	195	187	180	
21.							
$\%O_2$	17.09	15.70	15.61	16.33	16.50	16.50	
$\%CO_2$	2.85	4.05	4.40	4.10	3.95	3.00	
V_ESTPD	27.08	33.48	46.95	78.33	92.19	57.54	
VO_2	1.12	1.86	2.62	3.72	4.22	2.78	
MHR	118	133	161	180	187		
22.							
$\%O_2$	14.91	14.31	14.06	17.13	17.16	18.11	
$\%CO_2$	4.75	5.15	5.65	3.55	3.40	2.10	
V_ESTPD	24.01	24.90	36.20	102.06	107.01	75.41	
VO_2	1.53	1.76	2.62	3.97	4.16	2.10	
MHR	129	143	167	200	187		
23.							
$\%O_2$	15.91	15.96	15.54	15.41	16.10	16.29	15.93
$\%CO_2$	4.25	4.40	4.80	4.85	4.60	4.00	3.80
V_ESTPD	31.45	29.81	42.77	58.39	84.65	83.98	52.07
VO_2	1.65	1.53	2.38	3.34	4.16	4.06	2.78
MHR	105	117	140	166	196	180	187
24.							
$\%O_2$	16.80	15.93	16.38	16.91	16.75	17.30	17.05
$\%CO_2$	3.70	4.30	4.20	3.60	3.60	3.10	3.90
V_ESTPD	45.01	37.83	60.04	86.68	92.55	108.53	77.04
VO_2	1.91	1.95	2.80	3.60	4.02	4.11	3.00
MHR	125	125	167	180	187	195	

SUBJECT	300	600	900	1200	1500	1800	2100
25.							
$\%O_2$	15.58	15.43	15.63	15.81	16.78	15.79	16.70
$\%CO_2$	4.30	5.00	4.75	4.50	4.00	3.50	3.30
V_ESTPD	24.31	33.77	51.95	74.15	97.16	53.45	50.63
VO_2	1.31	1.91	2.84	3.93	4.09	2.85	2.28
MHR	117	124	149	173	180		
26.							
$\%O_2$	16.88	15.06	15.69	16.65	16.38	16.69	
$\%CO_2$	4.35	4.75	4.55	3.90	3.25	2.80	
V_ESTPD	23.14	27.76	46.45	84.09	82.52	70.93	
VO_2	.92	1.72	2.53	3.70	4.077	3.29	
MHR	111	134	158	191	187	176	
27.							
$\%O_2$	15.65	15.50	13.68	16.77			
$\%CO_2$	4.60	4.80	4.80	4.40			
V_ESTPD	19.70	33.21	51.28	84.02			
VO_2	1.08	1.87	4.07	3.46			
MHR	89	118	149	155			
28.							
$\%O_2$	18.21	17.15	16.25	15.88	16.78	16.78	
$\%CO_2$	3.10	3.60	4.30	4.70	4.10	3.70	
V_ESTPD	46.67	46.34	49.94	64.16	97.21	81.35	
VO_2	1.23	1.78	2.40	3.31	4.06	3.49	
MHR	105	119	144	173	184	187	
29.							
$\%O_2$	15.81	15.10	15.94	16.80	17.34	16.70	
$\%CO_2$	3.60	4.40	4.35	3.80	3.40	3.15	
V_ESTPD	22.66	31.68	52.60	95.86	104.77	73.92	
VO_2	1.26	1.97	2.72	4.06	3.83	3.16	
MHR	124	135	160	180	180	180	

SUBJECT	300	600	900	1200	1500	1800	2100
30.							
$\%O_2$	18.50	16.42	17.88	16.98	17.50		
$\%CO_2$	3.00	3.85	3.67	3.20	2.05		
V_ESTPD	39.08	37.16	63.62	85.20	105.76		
VO_2	.94	1.75	1.85	3.55	4.03		
MHR	107	127	173	195	204		
31.							
$\%O_2$	17.45	16.00	17.00	17.23	17.05	17.47	
$\%CO_2$	2.90	3.70	4.40	3.60	3.30	2.60	
V_ESTPD	36.47	47.69	58.82	103.08	99.22	85.63	
VO_2	1.33	2.52	2.25	3.861	4.02	3.17	
MHR	112	127	160	187	189	187	
32.							
$\%O_2$	16.48	15.63	15.01	16.61	17.09	17.30	
$\%CO_2$	3.20	4.30	4.80	4.10	3.20	2.70	
V_ESTPD	23.97	29.38	36.42	83.87	98.42	68.44	
VO_2	1.1507	1.639	2.27	3.688	3.967	2.665	
MHR	104	125	161	191	187	184	
33.							
$\%O_2$	16.25	15.50	14.85	15.36	16.36	16.00	
$\%CO_2$	4.50	4.80	5.40	5.20	4.80	4.35	
V_ESTPD	19.15	32.50	40.33	57.79	87.02	60.03	
VO_2	.91	1.82	2.53	3.29	3.94	3.06	
MHR	122	129	158	180	195	187	
34.							
$\%O_2$	17.25	16.83	16.09	16.53	17.35	17.35	
$\%CO_2$	2.75	3.35	4.00	4.10	3.15	2.7	
V_ESTPD	25.92	40.00	45.96	78.54	105.73	69.08	
VO_2	1.02	1.91	2.34	3.56	3.93	2.65	
MHR	110	141	170	191	195	191	

SUBJECT	300	600	900	1200	1500	1800	2100
35.							
$\%O_2$	16.03	15.10	15.78	16.05	17.60	17.45	
$\%CO_2$	4.20	4.80	4.70	4.70	3.60	3.10	
V_ESTPD	19.86	29.30	46.22	70.76	119.65	107.04	
VO_2	1.01	1.79	2.57	3.50	3.92	3.86	
MHR	117	130	158	187	196	187	
36.							
$\%O_2$	15.41	16.36	15.85	16.69	16.94	16.18	
$\%CO_2$	4.30	4.60	4.60	4.00	3.80	3.40	
V_ESTPD	24.77	39.23	54.50	81.53	96.45	59.06	
VO_2	1.45	1.80	2.83	3.53	3.91	3.03	
MHR	99	125	158	195	191	180	
37.							
$\%O_2$	15.15	15.13	16.14	16.80	16.80	17.20	
$\%CO_2$	4.50	4.60	4.80	3.70	3.40	2.90	
V_ESTPD	20.97	32.97	48.58	84.50	89.66	75.47	
VO_2	1.29	2.02	2.34	3.60	3.89	3.00	
MHR	136	157	191	204	204	195	
38.							
$\%O_2$	14.90	13.87	12.99	14.97	16.21		
$\%CO_2$	4.70	5.50	5.90	5.50	4.70		
V_ESTPD	16.81	22.05	33.43	49.84	81.85		
VO_2	1.08	1.60	2.84	3.04	3.88		
MHR	105	117	155	180	187		
39.							
$\%O_2$	17.16	17.33	15.74	16.54	17.40	17.92	
$\%CO_2$	3.30	4.30	4.60	3.80	2.50	2.05	
V_ESTPD	21.57	30.00	50.10	85.06	101.61	72.45	
VO_2	.85	1.03	2.69	3.42	3.88	2.38	
MHR	124	127	158	176	166	173	

SUBJECT	300	600	900	1200	1500	1800	2100
40.							
$\%O_2$	15.39	15.13	15.76	16.83	17.20	17.29	
$\%CO_2$	4.45	4.60	4.60	3.80	3.25	2.60	
V_ESTPD	18.37	25.26	46.70	85.39	99.21	82.57	
VO_2	1.07	1.55	2.49	3.59	3.84	3.25	
MHR	114	138	173	195	195	191	
41.							
$\%O_2$	15.85	15.36	16.63	17.34	16.04		
$\%CO_2$	3.70	4.20	4.60	4.00	3.40		
V_ESTPD	19.55	38.80	50.28	83.31	71.46		
VO_2	1.01	2.31	2.13	2.91	3.80		
MHR	117	130	155	184	173		
42.							
$\%O_2$	16.74	16.00	16.38	17.49	17.49		
$\%CO_2$	3.00	4.40	4.15	3.30	2.60		
V_ESTPD	30.43	37.42	55.89	108.73	92.16		
VO_2	1.36	1.91	2.61	3.80	3.39		
MHR	123	141	173	191	184		
43.							
$\%O_2$	16.80	14.85	14.44	16.36	16.46	16.70	
$\%CO_2$	4.15	5.15	5.50	4.65	3.90	3.45	
V_ESTPD	31.68	32.10	43.40	82.68	79.49	71.83	
VO_2	1.31	2.03	2.94	3.78	3.69	3.20	
MHR	134	141	164	187	187	187	
44.							
$\%O_2$	16.83	16.31	15.98	17.26	17.45	17.45	
$\%CO_2$	3.35	3.90	4.15	3.45	2.95	2.60	
V_ESTPD	27.86	35.42	53.64	99.99	100.34	92.52	
VO_2	1.20	1.71	2.77	3.74	3.54	3.45	
MHR	132	141	161	195	180		

SUBJECT	300	600	900	1200	1500	1800	2100
45.							
$\%O_2$	16.73	16.98	16.65	16.75	17.03	17.39	
$\%CO_2$	3.30	3.15	3.65	3.60	3.25	2.55	
V_ESTPD	27.49	41.85	59.59	85.16	81.87	62.53	
VO_2	1.226	1.749	2.58	3.797	3.349	2.38	
MHR	108	136	161	187	191	187	
46.							
$\%O_2$	15.79	15.76	16.01	15.51	16.34	16.60	
$\%CO_2$	4.00	4.30	4.65	4.90	4.30	2.95	
V_ESTPD	23.88	31.79	53.09	66.73	74.61	71.13	
VO_2	1.31	1.72	2.67	3.72	3.50	3.35	
MHR	136	148	173	195	195	191	
47.							
$\%O_2$	15.56	15.33	16.21	16.38	16.63	15.93	
$\%CO_2$	4.35	4.70	4.15	4.10	3.60	3.65	
V_ESTPD	23.25	31.54	57.37	79.22	75.07	51.97	
VO_2	1.31	1.86	2.81	3.72	3.36	2.79	
MHR	106	125	153	184	173	180	
48.							
$\%O_2$	15.94	15.46	15.46	16.68	16.68	17.08	
$\%CO_2$	4.15	4.50	4.65	4.10	3.55	2.85	
V_ESTPD	22.70	29.83	43.29	83.78	88.38	65.53	
VO_2	1.19	1.71	2.47	3.61	3.71	2.71	
MHR	129	150	180	214	200	180	
49.							
$\%O_2$	17.48	16.53	16.03	16.75	16.68	17.38	
$\%CO_2$	2.70	3.50	4.00	4.00	3.20	2.60	
V_ESTPD	32.04	37.94	50.61	83.69	81.37	68.25	
VO_2	1.175	1.767	2.6105	3.5547	3.70	2.607	
MHR	110	136	167	214	200	200	

SUBJECT	300	600	900	1200	1500	1800	2100
50.							
$\%O_2$	16.23	15.15	16.10	16.25	17.19	17.06	
$\%CO_2$	4.10	4.60	4.65	4.35	3.50	2.90	
V_ESTPD	22.78	33.96	52.84	77.12	86.37	66.39	
VO_2	1.11	2.08	2.59	3.69	3.30	2.75	
MHR	136	150	173	187	195	187	
51.							
$\%O_2$	16.28	15.31	15.34	16.99	17.25	17.13	
$\%CO_2$	4.05	4.75	4.85	3.75	3.35	3.10	
V_ESTPD	24.72	29.55	44.52	90.86	90.16	70.84	
VO_2	1.19	1.73	2.59	3.64	3.42	2.83	
MHR	114	136	155	187	191	200	
52.							
$\%O_2$	15.72	15.89	15.98	17.38	17.17	17.18	
$\%CO_2$	3.85	4.25	4.30	3.85	3.20	2.75	
V_ESTPD	21.89	37.22	55.29	87.79	92.29	70.62	
VO_2	1.22	1.96	2.85	3.65	3.63	2.85	
MHR	129	145	173	187	180	187	
53.							
$\%O_2$	16.38	16.55	16.55	18.03	18.03	18.44	
$\%CO_2$	3.55	3.65	3.95	2.65	2.30	2.10	
V_ESTPD	26.11	40.69	58.90	115.69	117.91	86.64	
VO_2	1.26	1.85	2.65	3.36	3.63	2.24	
MHR	113	136	180	204	195	180	
54.							
$\%O_2$	17.35	17.03	16.99	17.37	17.72	17.44	
$\%CO_2$	3.10	3.50	3.80	3.40	3.20	2.60	
V_ESTPD	28.70	44.61	61.88	99.62	105.93	71.06	
VO_2	1.07	1.80	2.47	3.61	3.24	2.66	
MHR	118	136	170	192	195	187	

SUBJECT	300	600	900	1200	1500	1800	2100
55.							
$\%O_2$	16.06	15.70	15.70	16.26	17.95	17.43	
$\%CO_2$	3.85	4.25	4.60	4.20	2.85	2.65	
V_ESTPD	24.63	33.29	46.88	68.65	118.51	61.31	
VO_2	1.27	1.83	2.54	3.31	3.60	2.30	
MHR	129	145	164	187	195	177	
56.							
$\%O_2$	15.70	16.23	16.30	16.30	17.45	18.34	
$\%CO_2$	4.10	4.30	4.20	4.40	3.60	2.00	
V_ESTPD	20.99	36.69	52.00	72.03	103.79	124.10	
VO_2	1.16	1.77	2.48	3.39	3.60	3.43	
MHR	115	130	144	173	180	163	
57.							
$\%O_2$	16.66	16.53	16.43	17.74	17.53	17.85	
$\%CO_2$	3.70	4.00	4.20	3.60	2.70	2.40	
V_ESTPD	23.59	38.22	55.48	92.96	84.49	59.76	
VO_2	1.05	1.73	2.55	3.59	3.05	1.96	
MHR	113	145	184	191	187		
58.							
$\%O_2$	16.88	16.38	16.86	17.80	17.05	17.49	
$\%CO_2$	3.30	4.20	4.50	4.20	3.70	3.80	
V_ESTPD	28.87	34.19	48.90	75.65	90.08	77.06	
VO_2	1.23	1.59	1.94	2.17	3.56	2.59	
MHR	110	132	155	173	183	180	
59.							
$\%O_2$	15.73	15.00	15.05	15.87	16.14		
$\%CO_2$	4.20	5.10	5.00	4.80	4.40		
V_ESTPD	21.37	30.68	42.55	56.01	72.47		
VO_2	1.17	1.89	2.61	2.88	3.56		
MHR	114	155	157	166			

SUBJECT	300	600	900	1200	1500	1800	2100
60.							
$\%O_2$	16.14	16.28	14.90	16.15	16.55		
$\%CO_2$	3.45	3.60	4.45	3.80	3.60		
V_ESTPD	33.87	43.86	54.93	59.17	53.47		
VO_2	1.84	2.30	3.55	3.00	2.64		
MHR	105	127	149	173	173		
61.							
$\%O_2$	16.14	15.88	15.81	16.05	17.26	16.71	
$\%CO_2$	3.90	5.00	4.95	4.65	3.80	3.25	
V_ESTPD	23.32	29.54	44.71	60.70	93.05	78.85	
VO_2	1.18	1.50	2.32	3.01	3.45	3.54	
MHR	117	129	155	180	202		
62.							
$\%O_2$	15.70	15.13	15.70	15.69	17.58		
$\%CO_2$	4.55	5.35	4.90	5.20	3.50		
V_ESTPD	19.54	30.01	49.08	67.14	64.83		
VO_2	1.06	1.78	2.62	3.54	2.16		
MHR	107	132	150	173	191		
63.							
$\%O_2$	15.71	15.39	15.78	16.31	12.68	16.98	
$\%CO_2$	4.20	4.50	4.80	4.40	3.40	3.10	
V_ESTPD	23.58	33.67	51.59	73.28	109.45	79.34	
VO_2	1.30	1.97	2.33	3.44	3.54	3.12	
MHR	114	130	149	180	187	184	
64.							
$\%O_2$	15.38	14.74	14.33	15.79	16.13	16.41	
$\%CO_2$	4.00	4.60	5.15	4.70	3.50	3.50	
V_ESTPD	14.65	37.48	41.97	66.60	73.51	52.81	
VO_2	.88	2.49	2.94	3.46	3.79	2.92	

SUBJECT	300	600	900	1200	1500	1800	2100
65.							
$\%O_2$	16.06	15.46	16.28	16.69	16.16	16.43	
$\%CO_2$	3.50	4.16	4.10	3.80	3.15	3.00	
V_ESTPD	23.37	36.04	58.91	80.05	54.43	42.93	
VO_2	1.23	2.10	2.84	3.50	2.87	2.11	
MHR	127	150	187	195	167		
66.							
$\%O_2$	18.06	15.35	15.48	15.95	17.45	17.58	
$\%CO_2$	4.30	4.70	4.90	4.60	3.60	2.70	
V_ESTPD	23.08	30.94	44.73	68.52	93.42	69.26	
VO_2	.58	1.81	2.51	3.49	3.24	2.45	
MHR	90	107	140	166	184		
67.							
$\%O_2$	15.64	15.05	15.97	16.87	18.10	16.41	
$\%CO_2$	3.80	4.80	4.80	4.20	3.80	3.30	
V_ESTPD	21.02	34.62	55.85	86.27	94.86	53.55	
VO_2	1.22	2.14	2.81	3.49	2.46	2.44	
MHR	107	134	161	187	184		
68.							
$\%O_2$	17.59	16.31	15.85	16.93	16.59		
$\%CO_2$	3.00	4.00	4.40	3.60	3.45		
V_ESTPD	41.82	40.93	54.48	88.42	75.33		
VO_2	1.44	1.97	2.88	3.65	3.46		
MHR	118	123	155	180			
69.							
$\%O_2$	17.45	15.73	15.96	15.95	16.60	16.95	
$\%CO_2$	3.50	4.35	4.80	5.10	4.15	3.15	
V_ESTPD	29.39	32.70	48.05	65.23	78.48	77.64	
VO_2	1.03	1.78	2.42	3.24	3.45	3.28	
MHR	105	113	145	180	187	187	

SUBJECT	300	600	900	1200	1500	1800	2100
70.							
$\%O_2$	16.87	16.42	15.86	16.45	16.63	17.50	
$\%CO_2$	3.50	3.60	3.80	3.70	4.00	2.70	
V_ESTPD	35.03	39.16	53.23	76.40	62.86	70.18	
VO_2	1.48	1.87	2.90	3.42	2.76	2.56	
MHR	155	155	177	187	187	191	
71.							
$\%O_2$	16.73	16.73	16.69	17.17	17.31		
$\%CO_2$	3.65	3.40	3.90	3.40	2.65		
V_ESTPD	46.07	37.62	61.66	87.39	88.05		
VO_2	1.92	1.68	2.72	3.39	3.42		
MHR	129	155	187	195	187		
72.							
$\%O_2$	18.21	17.12	18.58	17.38	17.37		
$\%CO_2$	3.05	3.70	1.90	3.40	4.00		
V_ESTPD	45.32	53.85	79.95	93.35	98.13		
VO_2	1.20	2.08	1.99	3.36	3.398		
MHR	105	114	135	169	166		
73.							
$\%O_2$	15.42	15.00	15.78	16.47	17.60		
$\%CO_2$	4.20	4.60	4.70	4.60	3.00		
V_ESTPD	21.08	29.46	42.02	76.19	92.46		
VO_2	1.24	1.86	2.22	3.38	3.17		
MHR	129	147	167	180	173		
74.							
$\%O_2$	15.54	14.93	15.83	17.34	16.68		
$\%CO_2$	4.10	4.90	4.45	3.40	3.05		
V_ESTPD	18.34	28.70	53.42	91.95	60.25		
VO_2	1.06	1.81	2.83	3.37	2.76		
MHR	130	155	184	195	187		

SUBJECT	300	600	900	1200	1500	1800	2100
75.							
$\%O_2$	16.51	15.39	15.39	16.78	17.49	16.98	
$\%CO_2$	3.30	4.40	4.65	3.90	3.40	2.90	
V_ESTPD	23.06	29.69	42.68	74.94	101.81	78.50	
VO_2	1.15	1.82	2.47	3.17	3.53	3.34	
MHR	105	115	136	170	180	180	
76.							
$\%O_2$	16.13	15.42	15.63	16.75	17.37	17.47	
$\%CO_2$	3.90	4.70	5.00	4.30	3.40	3.10	
V_ESTPD	21.48	28.25	42.03	79.12	80.36	63.41	
VO_2	1.09	1.62	2.27	3.30	2.91	2.27	
MHR	117	136	164	191	180	191	
77.							
$\%O_2$	15.73	15.15	15.45	15.38	16.63	16.80	
$\%CO_2$	4.20	4.60	4.60	3.80	3.30	3.00	
V_ESTPD	24.54	33.14	50.03	51.64	71.32	58.84	
VO_2	1.35	2.03	2.85	3.11	3.27	2.62	
MHR	113	136	167	195	180		
78.							
$\%O_2$	16.25	14.88	15.45	16.66	16.48		
$\%CO_2$	4.35	5.00	5.10	4.05	3.25		
V_ESTPD	16.30	24.64	48.13	74.38	53.39		
VO_2	.78	1.57	2.69	3.23	2.56		
MHR	114	138	176	195	187		
79.							
$\%O_2$	16.05	15.43	14.90	15.97	16.70		
$\%CO_2$	3.80	4.50	5.30	4.10	3.20		
V_ESTPD	18.70	28.41	38.60	61.68	42.84		
VO_2	.97	1.64	2.41	3.22	1.94		
MHR	109	150	180	184	180		

SUBJECT	300	600	900	1200	1500	1800	2100
80.							
$\%O_2$	17.13	15.85	16.17	15.87	16.75		
$\%CO_2$	3.80	4.70	4.90	5.00	3.40		
V_ESTPD	34.30	36.19	51.24	63.21	49.40		
VO_2	1.31	1.88	2.43	3.22	2.18		
MHR	124	144	180	186	180		
81.							
$\%O_2$	16.30	15.38	15.38	15.68	16.62	17.21	
$\%CO_2$	3.35	4.70	4.80	4.70	3.60	3.65	
V_ESTPD	23.86	29.25	44.60	59.37	57.42	82.61	
VO_2	1.19	1.70	2.56	3.21	2.48	3.10	
MHR	114	123	153	184	204	200	
82.							
$\%O_2$	18.10	17.17	16.62	17.88	17.84		
$\%CO_2$	3.70	3.90	4.30	3.30	2.60		
V_ESTPD	35.45	40.76	61.86	106.11	85.39		
VO_2	.93	1.52	2.68	3.18	2.77		
MHR	132	158	187	204	195		
83.							
$\%O_2$	16.90	15.60	16.28	17.20	17.67	17.05	
$\%CO_2$	3.90	4.80	4.80	4.30	3.40	3.20	
V_ESTPD	24.41	33.35	51.44	81.93	96.87	55.85	
VO_2	1.00	1.78	2.52	2.95	3.140	2.28	
MHR	113	132	164	187	187	180	
84.							
$\%O_2$	15.85	14.98	15.53	16.96	17.06		
$\%CO_2$	4.20	5.00	4.90	3.60	3.10		
V_ESTPD	20.46	26.57	44.88	76.51	49.40		
VO_2	1.09	1.65	2.49	3.13	2.02		
MHR	122	155	180	186	187		

SUBJECT	300	600	900	1200	1500	1800	2100
85.							
$\%O_2$	15.97	14.97	16.49	16.56			
$\%CO_2$	3.50	4.50	4.30	3.80			
V_ESTPD	22.07	34.29	59.14	68.34			
VO_2	1.17	2.18	2.66	3.10			
MHR	135	173	180	166			
86.							
$\%O_2$	17.25	16.41	17.53	18.25	18.48		
$\%CO_2$	3.50	4.20	3.50	2.80	2.05		
V_ESTPD	36.60	40.70	77.87	115.50	104.91		
VO_2	1.37	1.87	2.64	3.08	2.69		
MHR	115	147	180	187	196		
87.							
$\%O_2$	17.97	16.21	15.50	16.58	16.44	16.53	
$\%CO_2$	3.70	4.20	4.80	4.30	4.10	3.00	
V_ESTPD	32.71	39.64	42.81	69.53	48.13	38.23	
VO_2	.92	1.93	2.40	3.07	2.22	1.94	
MHR	107	132	155	187	187	187	
88.							
$\%O_2$	17.34	17.00	16.81	17.52	18.11	17.51	
$\%CO_2$	3.20	3.40	3.75	3.05	2.85	2.35	
V_ESTPD	32.19	46.27	64.20	105.05	116.81	51.06	
VO_2	1.19	1.89	2.72	3.70	3.31	2.11	
MHR	130	164	187	209	191		
89.							
$\%O_2$	15.90	15.22	15.40	17.39	18.49		
$\%CO_2$	4.20	4.80	4.60	3.80	4.00		
V_ESTPD	24.58	34.07	48.28	86.73	100.32		
VO_2	1.30	2.03	2.80	3.03	2.05		
MHR	112	135	155	180	180		

SUBJECT	300	600	900	1200	1500	1800	2100
90.							
$\%O_2$	19.25	13.88	15.23	16.61	15.84		
$\%CO_2$	.80	5.00	5.00	3.80	3.60		
V_ESTPD	2.33	18.17	42.14	66.04	45.78		
VO_2	.46	1.38	2.49	2.96	2.52		
MHR	141	170	195	200	195		
91.							
$\%O_2$	17.43	17.21	17.44	17.35	17.21		
$\%CO_2$	3.80	3.40	3.30	3.20	2.60		
V_ESTPD	44.22	61.51	75.54	71.79	67.70		
VO_2	1.64	2.35	2.68	2.64	2.69		
MHR	132	147	191	180	180		
92.							
$\%O_2$	17.13	16.68	16.50	17.15	17.95	17.83	
$\%CO_2$	3.60	4.40	4.65	4.25	3.60	3.00	
V_ESTPD	21.31	31.22	44.23	70.30	96.60	90.06	
VO_2	.82	1.32	1.94	1.95	2.74	2.83	
MHR	102	117	149	173	195	180	
93.							
$\%O_2$	15.60	15.73	17.35	18.15	18.63		
$\%CO_2$	4.50	4.70	2.90	2.80	2.25		
V_ESTPD	21.47	35.11	74.44	98.64	77.47		
VO_2	1.20	1.88	2.82	2.76	1.81		
MHR	129	150	178	176	173		
94.							
$\%O_2$	15.96	16.01	16.86	17.95	17.83		
$\%CO_2$	4.10	4.45	4.20	3.05	2.75		
V_ESTPD	20.55	35.65	61.68	92.82	59.56		
VO_2	1.07	1.81	2.50	2.77	1.91		
MHR	122	155	195	204	200		

SUBJECT	300	600	900	1200	1500	1800	2100
95.							
$\%O_2$	17.81	15.99	17.16	17.97	17.30		
$\%CO_2$	3.50	4.70	3.80	3.40	2.80		
V_ESTPD	37.87	39.23	63.21	95.42	63.90		
VO_2	1.15	1.97	2.39	2.73	2.47		
MHR	153	180	200	209	200		
96.							
$\%O_2$	17.33	16.70	16.70	17.20	18.16	18.08	
$\%CO_2$	3.80	4.25	4.65	4.45	3.60	2.60	
V_ESTPD	22.62	33.05	45.31	64.81	105.91	70.97	
VO_2	.81	1.40	1.88	2.31	2.72	2.08	
MHR	130	155	180	195	204	180	
97.							
$\%O_2$	16.59	16.00	16.19	17.03	17.72		
$\%CO_2$	3.50	4.40	4.40	4.00	2.70		
V_ESTPD	25.99	35.58	55.97	38.86	49.54		
VO_2	1.19	1.81	2.72	1.52	1.66		
MHR	96	132	184	187	184		
98.							
$\%O_2$	17.58	15.93	17.11	17.60			
$\%CO_2$	4.00	4.70	4.10	3.40			
V_ESTPD	27.17	35.92	65.02	81.56			
VO_2	.87	1.83	2.45	2.72			
MHR	112	149	180	180			
99.							
$\%O_2$	14.21	14.07	13.74	16.17	14.65		
$\%CO_2$	4.90	5.80	6.10	4.60	4.40		
V_ESTPD	15.20	23.00	31.74	46.29	26.88		
VO_2	1.10	1.65	2.38	2.23	1.83		
MHR	125	138	167	187	180		

SUBJECT	300	600	900	1200	1500	1800	2100
100.							
$\%O_2$	18.29	16.56	16.83	17.76	17.05		
$\%CO_2$	2.60	4.10	4.50	3.25	3.00		
V_ESTPD	43.84	38.08	53.32	47.23	49.88		
VO_2	1.17	1.70	2.34	1.50	1.95		
MHR	111	130	184	200	195		

RETEST RAW SCORES FOR RELIABILITY OF ASTRAND
BICYCLE ERGOMETER MAXIMAL OXYGEN CONSUMPTION TEST

	WORK LEVEL EXPRESSED IN KILOPOND METERS PER MINUTE						
SUBJECT	300	600	900	1200	1500	1800	2100
5.							
$\%O_2$	15.76	15.19	14.46	15.46	17.00	17.23	17.24
$\%CO_2$	4.50	4.90	5.50	5.10	4.10	3.60	3.15
V_ESTPD	20.95	50.08	36.00	60.12	109.32	115.02	74.89
VO_2	1.12	3.00	2.43	3.36	4.27	4.31	2.89
MHR	110	120	155	176	200	196	191
7.							
$\%O_2$	17.13	16.97	16.20	16.50	17.13	16.30	
$\%CO_2$	3.10	3.50	3.80	3.80	3.80	3.00	
V_ESTPD	35.14	40.73	49.93	63.37	86.86	78.84	
VO_2	1.41	1.67	2.49	2.93	3.32	4.01	
MHR	115	122	143	170	184	173	
14.							
$\%O_2$	15.79	15.59	15.59	16.50	17.10	17.55	
$\%CO_2$	4.45	4.55	4.75	4.20	3.90	2.85	
V_ESTPD	21.84	35.49	48.32	74.83	98.78	71.05	
VO_2	1.17	1.98	2.66	3.37	3.78	2.52	
MHR	107	129	155	191	200	195	
26.							
$\%O_2$	16.45	15.89	15.66	17.44	17.38	19.20	
$\%CO_2$	4.05	4.70	4.95	3.70	3.10	2.65	
V_ESTPD	28.14	38.52	49.43	103.27	108.25	119.33	
VO_2	1.30	1.98	2.66	3.57	3.99	1.80	
MHR	113	130	155	184	173	176	
45.							
$\%O_2$	16.86	17.09	17.00	17.54	17.76		
$\%CO_2$	3.30	3.50	3.70	2.95	2.90		
V_ESTPD	32.04	45.51	70.23	81.18	50.14		
VO_2	1.38	1.80	2.82	2.86	1.64		
MHR	125	136	167	187	180		

SUBJECT	300	600	900	1200	1500	1800	2100
46.							
$\%O_2$	17.79	17.29	17.11	17.26	17.46	17.51	17.89
$\%CO_2$	2.90	3.50	3.35	3.50	3.50	2.85	2.25
V_ESTPD	43.04	51.77	68.27	86.00	116.77	113.60	73.95
VO_2	1.39	1.89	2.62	3.21	4.07	4.08	2.42
MHR	132	145	161	187	200	195	
49.							
$\%O_2$	17.45	16.21	16.27	17.63	17.05		
$\%CO_2$	3.00	4.10	4.20	3.50	3.10		
V_ESTPD	32.88	34.78	51.21	97.17	86.31		
VO_2	1.28	1.70	2.46	3.17	3.54		
MHR	129	155	187	214	200		
57.							
$\%O_2$	17.53	16.88	16.67	17.12	17.65		
$\%CO_2$	3.40	3.80	3.85	3.50	2.55		
V_ESTPD	35.32	44.04	63.17	89.48	80.02		
VO_2	1.21	1.82	2.77	3.50	2.79		
MHR	117	138	173	187	180		
64.							
$\%O_2$	15.64	15.38	15.55	16.31	17.16	17.06	
$\%CO_2$	4.65	4.90	5.05	4.70	4.05	3.30	
V_ESTPD	21.81	33.74	45.86	73.05	98.44	67.06	
VO_2	1.20	1.94	2.52	3.37	3.66	2.71	
MHR	130	150	167	187	195	191	
71.							
$\%O_2$	17.30	16.36	16.19	17.30	16.83		
$\%CO_2$	3.15	3.95	4.30	3.70	3.10		
V_ESTPD	27.86	35.04	51.02	91.89	71.35		
VO_2	1.05	1.66	2.49	3.34	3.13		
MHR	115	143	180	195	187		

SUBJECT	300	600	900	1200	1500	1800	2100
76.							
$\%O_2$	15.66	15.40	15.16	16.91	16.88	17.28	
$\%CO_2$	4.00	4.35	4.70	3.90	3.00	3.45	
V_ESTPD	18.33	28.93	40.85	77.13	53.15	81.67	
VO_2	1.03	1.69	2.48	3.14	2.31	2.71	
MHR	.02	136	167	191	187	191	
81.							
$\%O_2$	16.33	15.33	15.65	16.94	17.21	17.30	
$\%CO_2$	3.95	4.40	4.55	3.95	3.70	2.90	
V_ESTPD	24.20	38.14	46.12	81.94	90.62	64.55	
VO_2	1.17	2.26	1.01	3.29	3.39	2.48	
MHR	117	127	167	187	187	184	
83.							
$\%O_2$	16.80	16.15	16.00	16.43	17.65	16.25	
$\%CO_2$	3.65	4.20	4.40	4.20	3.30	3.05	
V_ESTPD	29.07	34.05	49.20	75.50	119.22	80.20	
VO_2	1.24	1.69	2.50	3.47	3.93	4.12	
MHR	113	129	161	187	204	195	
88.							
$\%O_2$	16.38	15.89	16.54	17.43	17.05		
$\%CO_2$	3.40	4.25	4.05	3.35	2.85		
V_ESTPD	22.46	37.05	58.81	85.85	58.69		
VO_2	1.10	1.94	2.65	3.06	2.45		
MHR	136	173	195	204	205		
99.							
$\%O_2$	13.44	12.63	13.90	16.28	16.99	16.01	
$\%CO_2$	5.50	6.50	5.65	4.20	3.00	3.25	
V_ESTPD	12.77	17.43	32.16	63.81	72.73	37.79	
VO_2	1.02	1.58	2.39	3.06	3.06	2.04	
MHR	107	138	173	195	187	195	

SUBJECT	300	600	900	1200	1500	1800	2100
100.							
$\%O_2$	17.39	16.34	16.68	18.01	17.71		
$\%CO_2$	2.95	4.10	4.00	2.95	2.40		
V_ESTPD	30.83	36.69	59.11	82.01	62.58		
VO_2	1.14	1.74	2.56	2.41	2.17		
MHR	115	141	180	204	195		

APPENDIX D

CORRECTIONS

CORRECTIONS FOR THE BECKMAN E-2 OXYGEN ANALYZER

The accuracy of this instrument was tested against two micro-Scholander instruments operated by laboratory technicians in the Cardiopulmonary Laboratory of the University of Alberta Hospital and the laboratory of the Department of Physiology at the University of Alberta.

The values obtained with the two Scholanders were averaged and a regression equation based on the Beckman reading and the Scholander values was calculated. This equation was found to be,

$$Y' = .893X + 2.22$$

where $Y' \doteq$ the corrected percentage of oxygen

and X' = the percentage of oxygen as read on the Beckman E-2 analyzer.

The discrepancy was found to be due to impure nitrogen which was used as a calibration gas.

Based on the above regression equation, a second regression line was calculated which permitted direct correction of oxygen consumption values. This equation was found to be,

$$Y' = .871X + .0044$$

where Y' = corrected oxygen consumption in liters per minute

and $X \div$ oxygen consumption value obtained on the basis of the uncorrected percentage of oxygen as obtained on the Beckman analyzer.

After testing with the same Micro-Scholanders, the Godart Capnograph infra-red carbon dioxide analyzer was found to give accurate readings.

The raw scores contained in Appendix C have not been corrected for the oxygen discrepancy but have been changed to the corrected volumes.

CORRECTIONS FOR AMERICAN CO. GAS METER #802

This meter was tested for its volume determinations using as standards the large Tissot tank in the Faculty of Physical Education Laboratory and a smaller Tissot tank in the Cardio-pulmonary Laboratory at the University Hospital. It was found to be recording volume readings in excess of actual volumes pumped, as indicated by the Tissot tanks. A second American Meter Co. gas meter, in use in the University Hospital, was found to give extremely accurate readings when compared to the same Tissot tanks.

The data collected was analyzed and a regression equation calculated. This equation was found to be,

$$Y = .22770 + .943099\ X$$

where Y = corrected volume

and X = volume as read on the American Meter Co. Gas Meter #802.

This regression equation was then used to calculate a oomplete set of correction tables. These tables also incorporate a factor for loss of volume during oxygen and carbon dioxide analysis, with the factor being considered as 300 c.c.

MAXIMAL OXYGEN CONSUMPTION VALUES OBTAINED IN THE ASTRAND BICYCLE ERGOMETER TEST EXPRESSED IN LITRES PER MINUTE

MAXIMAL OXYGEN CONSUMPTION TEST IN L/MIN

SUBJECT	MVO_2	SUBJECT	MVO_2	SUBJECT	MVO_2	SUBJECT	MVO_2
1	5.0366	26	3.5555	51	3.1748	76	2.8752
2	4.8646	27	3.5493	52	3.1661	77	2.8513
3	4.5249	28	3.5468	53	3.1643	78	2.8210
4	4.2976	29	3.5415	54	3.1481	79	2.8090
5	4.1120	30	3.5179	55	3.1400	80	2.8086
6	4.0867	31	3.5058	56	3.1393	81	2.8046
7	4.0536	32	3.4797	57	3.1303	82	2.7741
8	3.9897	33	3.4370	58	3.1052	83	2.7393
9	3.9500	34	3.4235	59	3.1051	84	2.7271
10	3.9326	35	3.4195	60	3.0965	85	2.7045
11	3.9239	36	3.4108	61	3.0918	86	2.6899
12	3.8952	37	3.3961	62	3.0877	87	2.6749
13	3.8803	38	3.3839	63	3.0848	88	2.6670
14	3.8716	39	3.3838	64	3.0550	89	2.6432
15	3.8542	40	3.3525	65	3.0529	90	2.5789
16	3.8368	41	3.3142	66	3.0442	91	2.4754
17	3.8202	42	3.3142	67	3.0411	92	2.4693
18	3.7471	43	3.2950	68	3.0181	93	2.4560
19	3.7409	44	3.2619	69	3.0093	94	2.4173
20	3.7332	45	3.2529	70	2.9876	95	2.3822
21	3.6800	46	3.2453	71	2.9832	96	2.3752
22	3.6278	47	3.2445	72	2.9640	97	2.3735
23	3.6240	48	3.2358	73	2.9525	98	2.3709
24	3.5842	49	3.2271	74	2.9368	99	2.0769
25	3.5668	50	3.2183	75	2.9089	100	2.0451